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The ignited oil and gas sent up a roaring column of flame over 200 feet high.

A BURNING OIL WELL.—[See page 343.]

Science in the War and After the War*

How Present Conditions Are Being Met, and the Coming Commercial Conflict

It is universally acknowledged that the outcome of the present war must be an entirely new chapter in human history and a point of fresh departure in social, economical, and intellectual life. Hence it is well to begin even now to take stock of our resources, to examine not only the reasons for our deficiencies but the directions of our reforms. Particularly are we concerned with the improved attitude which we shall have to take nationally with regard to all that study and knowledge which we call science and scientific research and invention. Hence, an important matter is to consider the position of science in the war and after the war.

Scientific knowledge is the accumulation of exact information concerning the facts and laws of nature, and the scientific method is the process by which we gain it, viz., by experiment or observation and logical deduction therefrom.

The cardinal fact which lies at the basis of all this nature-study is that there is no finality in it. Its possibilities are infinite, and we can never touch bottom in all that there is to be known about the simplest objects or phenomena of nature.

Hence the very essence of scientific study is that the votary should himself make some advances. Merely to know what others have done or discovered may be necessary, but this alone does not make a scientific student. Accordingly, the training required is that which imparts the power to make new knowledge, and the results must be judged by the degree to which it succeeds in so doing.

At this stage we may distinguish, however, two classes of workers. There are first those who are most interested in new facts or principles regardless of immediate utility, and, secondly, those who show ability in utilizing this knowledge in so-called useful applications of science. The first class embraces the purely scientific investigators and the second the inventors.

The public is, unfortunately, apt to attach more importance to the inventions than to the investigations, regardless of the fact that there could be no applications if there were no knowledge to apply. This failure to recognize the value and unspeakable importance of a progressive disinterested study of nature is a characteristic British quality, and it is something very much more serious than a mere national trait or idiosyncrasy.

Philosophical students of politics have long recognized that all forms of government have their special defects, and democratic or representative parliamentary government is no exception. One of the chief defects of the latter is that the men who gain the upper hand are too often the fluent or persuasive speakers or those who are skilled in managing public assemblies and masters in oratory and debate.

Hence, as Mr. F. S. Oliver points out in his very suggestive book, "Ordeal by Battle," in all countries where representative government prevails, this type of leader exercises a considerable and predominant influence on public affairs. But with the professional speaker and politician an over-great importance attaches generally to phrases and to words. Success with them depends very much on how a thing is put, and the form of expression often overrules even the subject-matter itself. But the whole object of scientific work is the discovery of the truth, and not its obscuration. Therefore the ascertainment of fact or principle is in all this work of infinitely more value than the form of words in which it is expressed. Hence to the politician there is a certain uncongeniality about the scientific habit of mind, while the man of serious scientific training becomes at times impatient of the methods of the party politician, which have not facts at the back of them.

Accordingly, the principal idea which it is necessary to instill into the public mind and drive home by every means is that our chief concern should be to bring the scientific method to bear upon all the affairs of the nation.

The second equally important truth is that the disinterested but systematic study of nature is of primary importance for national well-being. By disinterested study we mean pure scientific research not undertaken mainly for commercial reasons. Pope, I think, tells us that the proper study of mankind is man; but an even more important object of study for man is that of nature, and if we undertake that properly all other things in the way of applications will be added unto us. The point to notice, however, is that it is not everyone who possesses the necessary turn of mind for scientific investigation. There is a mysterious aptitude in some children for music, drawing, or other pursuits, and suitable training cultivates it. It is the same with the ability to discover or invent. Hence the primary duty of the nation with regard to its children is from the very earliest days to begin with them the study of nature, not in the repulsive form of learning things out of books, but by taking the child direct to the lap of Mother Nature and letting her teach the lessons about flowers, animals, stars, and earth structure.

All this, of course, means expenditure, but the nation has to learn this hard lesson, that education of the right kind cannot be given without wise and large outlay, and that there is nothing so expensive in the long run as cheap education. Another thing that has to be drilled into the public mind at all costs is that there are no short cuts to national efficiency or scientific pre-eminence.

The moment a deficiency is discovered, the tendency of the public is to cry out for some quick remedy; but quick remedies are very often quack remedies at best. We require, therefore, in the first place an entirely altered attitude of mind on the part of our public men, statesmen, and above all editors and managers of great daily newspapers toward scientific work, research, and teaching. We want a far greater appreciation of its supreme importance and of the attention that should be given to the cultivation of it under the guidance of expert leaders. The small degree to which genuine scientific work is appreciated, contrasted with mere sensational announcements not based on genuine discoveries or inventions, is seen in the treatment of scientific work by the daily press, which, after all, only reflects the attitude of mind of the general public. Compare, for instance, the attention accorded before the war to politics, amusement, and fashion, and that accorded to accounts of scientific researches or lectures, in the principal daily papers. Worse still, some of them are apparently easily led to take up and boom perfectly unscientific but sensational announcements.

The daily press, which has such immense influence on public opinion, should exercise wise guidance in these matters, aided by competent scientific opinion, yet with discrimination and care not to denounce novelty merely because it is new or strange.

Turning to the applications of science in the war, we can mention four chief departments of it under the headings: chemical, mechanical, electrical, and physical, which cover such appliances as high explosives, aeroplanes and dirigibles, submarines, wireless telegraphy, and range-finders. I shall not attempt to discuss the details of a fraction of all these applications, but just touch briefly on two departments which happen to have occupied my own attention during the vacation, viz., range-finders and wireless telegraphy from aeroplanes.

An extremely important matter in all war with projectiles is to ascertain the exact distance of the objective, whether it be ship or gun or building. The range of the projectile depends on the angle of elevation of the gun and the character of the ammunition and several other factors.

The proper setting of the gun can, of course, be determined by trial shots, but the larger the gun the more expensive this process, and the more necessary not to let the enemy know anything until a shot or shell falls exactly where it can do most damage to him.

Range-finders have for their object to determine this distance by some optical appliance. They are divided into two classes: First, prism or base range-finders; and, secondly, subtend range-finders. We can explain the principle of these by reference to our eyes and the method by which we roughly judge the distance of an object. When we look at an object the optic axes of the eyes converge on it, and by long practice we are able to appreciate the inclination of the axes. The centers of the eyes are about 2½ inches apart. Hence, we have a very short-based isosceles triangle, but we are enabled by our muscular sense to give a rough guess as to the angles at the base and practically to infer something about the length of the triangle. Again, we do it in another way by estimating the relative sizes of the image of known objects, such as a man or house or other thing which is formed on the retina. Another thing which assists us is the amount of detail we see in the object looked at.

The range-finders used in war are only more exact applications of the same principles. One of the most accurate is that of Profs. Barr and Stroud. This is a base or prism range-finder. It consists of a tube varying from half a meter to two meters, about 6 feet in length. At the ends of this tube are two totally reflecting prisms, which receive rays from the object and send them down the tube. At each end of the tube is an object glass, which forms an image which is received on a peculiarly cut prism at the center and by an eye-piece. The arrangement virtually forms a sort of double telescope corresponding to two eyes set 6 feet apart. When the observer looks into the right eye-piece he sees a field of view, which is divided into two parts, one produced by light coming into one object glass, and the other by that coming in at the other. If the object seen is a mast, say, of a ship, it appears broken in two parts. The observer can rectify or bring into agreement these two parts of the image by moving to or fro in the tube a thin prism. The position of this prism is read off on a scale seen with the left eye-piece. This scale shows the distance in yards of the object.

In the next place there are range-finders called subtend range-finders, which depend on the measurement of the size of an image of a known object. When we look at an object either with the eye or with a telescope at different distances, it appears to be smaller the farther away we are from it. In the case of the eye we have no means of measuring accurately this variation in size except by comparing the apparent size of the distant object with some near object the size of which is known. Hence, judging distance by the eye requires long training, as all sportsmen, sailors, and travelers know.

Moreover, we are apt to be deceived as to the apparent size. Ask anyone, for instance: How large appears the full moon? Many people would say, as large as a shilling —meaning that it has the same apparent angular magnitude as a shilling seen at 10 inches or 1 foot, which is the usual distance we hold a book or paper when reading.

But now, if you try the experiment, you will find that the full moon is covered by a very small pencil, like a pocket-book or dance-programme pencil, held at 10 inches from the eye. In scientific language, the apparent size of the moon is about half a degree, which means that it is covered by an object one tenth inch in diameter held 1 foot from the eye.

A man 6 feet high would subtend the same angle at a distance of 720 feet. Hence, you can tell the distance of a man by ascertaining the distance at which an object of known size, say a pencil, must be held so as just to cover his height. An ordinary pencil ¼ inch in diameter held horizontally at arm's length (= 2 feet) would just cover a man 5 feet 8 inches high at a distance of 544 feet, or 181 yards. The subtend range-finder works on the principle of measuring the angular magnitude of the object. One way of doing this is to place in the focus of the eye-piece a plate of glass with divisions ruled on it with a diamond. If we know how many divisions are covered by an object of known height at a known distance, we can tell the distance of any other object of known height.

It is very seldom, however, that we do know the exact height of the object, and, moreover, it is very difficult to count up accurately many very small divisions ruled on glass when the object seen is at all dark.

During the vacation I have been turning attention to methods for overcoming some of these difficulties. As these inventions are being submitted to the Ministry of Munitions, I do not think it desirable to go into details as to the methods, but I will tell you the results. I have invented three forms of range-finder—one which is an improved subtend range-finder with which I can find the distance of any object the dimensions of which are known, whether height or width, or any part of it. Also I have invented methods for using two such instruments to measure the distance of objects the dimensions of which are not known. In the second place, I have invented a simple form of base range-finder which measures what is called in astronomy the parallax of any distant object, and hence determines its distance. In the third place, I have devised a simple form of depression or elevation angle meter by means of which the height of any hill, and also the distance of any object from it, or from an elevated position, can be determined by an observer standing at the top of the hill, provided that he can also see two marks placed at the base in line with the point of observation on the hill and at a known distance apart. These instruments are simple and inexpensive to construct, and give an accuracy of measurement quite sufficient to direct rifle or artillery fire or bomb throwing in trenches. One great advantage of my range-finder is that it can be used with a periscope from the bottom of a trench so that the observer need not be exposed at all, but can determine the distance of the enemy's trench by observation on any post of a wire entanglement or stick or rock or anything with a sharp outline. Another principle which may be applied in making a range-finder, which I have also done in my instruments, is to observe the variation in the size of an object as seen in a small telescope by moving away from it a certain distance. Thus, suppose that a man was seen at a distance of 200 yards, or 600 feet, then his apparent height would be covered by the width of a pencil held about 2 feet from the eye. Suppose the

* An introductory lecture delivered at University College, London, on October 6th, by Prof. J. A. Fleming, F.R.S.

observer were to approach to half that distance or move in 300 feet, then the apparent size of the man would be doubled. If, however, the man were a mile away, then moving toward him 100 yards would only increase his apparent height by about 6 per cent. Hence we can determine the distance of an object by finding out how much the apparent size is increased when we move in toward it 100 yards or any assigned distance.

Another marvelous application of science in war is that of wireless telegraphy in connection with aeroplanes and airships as a means of scouting and rapid communication of intelligence.

In the case of aeroplanes the first of these is the weight of the apparatus. The military aeroplane is already loaded to its fullest extent. In addition to the pilot and observer and the bomb ammunition, it carries in nearly all cases some gun equipment. Hence any wireless apparatus must be made as light and compact as possible. A wireless transmitter of the so-called spark type involves three elements: (1) Some source of electromotive force such as a battery or dynamo; (2) an induction coil or transformer for creating a high electric potential or pressure; and (3) some form of condenser or Leyden jar which is charged and then discharged across a spark gap, thus creating rapid movements of electricity called electric oscillations. These oscillations are then caused to create others in a long wire called the aerial wire.

In the case of aeroplanes and airships the source of electromotive force is generally a small dynamo or alternator, which is coupled to the engine, and the voltage or pressure is raised to 30,000 volts or so by a small transformer sealed up in oil in a box. The condenser consists of metal plates sandwiched between sheets of glass or ebonite, and the spark balls between which the spark passes are also inclosed. The weight of the whole apparatus has to be kept below 100 pounds, and such apparatus has been designed having a weight of not more than 30 pounds. The French use a set weighing about 70 pounds. One of the difficulties is to dispose the aerial wire conveniently and safely. It is sometimes made of aluminium and stretched on insulators carried by light supports on the wings, but the difficulty is to obtain in this way sufficient length. One plan adopted is to coil the wire on a reel, which the observer can uncoil and let it float out behind the aeroplane.

The wire must be connected to the reel by a safety catch so as to be released at once if it catches in trees or buildings. By this means an aerial wire of 100 feet in length can be employed. The observer has near his hand a key by which he controls the spark discharges and so sets up in the aerial wire groups of electric oscillations which create electric waves in the ether, and signal the message in Morse code.

In this manner there is not much difficulty in equipping aeroplanes with transmitters which will send messages 30 miles or so to a corresponding earth station.

These latter are the military portable motor-car or pack stations, the details of which were described in a lecture given here last year on "Wireless Telegraphy in War."

The receiving arrangements used on aeroplanes comprise a head-telephone which is worn by the observer associated with some simple form of detector such as a carborundum crystal, aided by which the observer hears the signals sent to him in Morse code as long and short sounds in the telephone.

The noise of the aeroplane engine and that of the rush of air renders this method of aural reception a matter of great difficulty, especially as the messages must be sent in secret code, and the observer must therefore hear every letter distinctly if the message is to be intelligible. Great efforts have been made to devise methods of reception which shall appeal to the eye by a visual signal rather than to the ear, but the exceedingly small electric currents set up in the aerial wire by the arriving waves make this a matter of extreme difficulty, and the problem has not yet been completely solved. There is then the difficulty caused by "jamming." If the signals from an aeroplane are picked up by a hostile station, this latter at once sends out powerful but unmeaning signals the object of which is to blur and drown out the reception or sending of signals by this aeroplane. Moreover, the sending of wireless signals by an aeroplane reveals its presence to hostile earth stations before it can be seen by the eye. Hence, wireless telegraphy may be a means of revealing the enemies' scouts, and it involves a certain kind of war in the ether as well as war in the air.

In the case of airships there are other difficulties as well, and it is interesting to note that there are special difficulties in connection with Zeppelins. These aerial monsters are, as everyone knows, constructed with a framework of aluminium, containing in its interior the eighteen or twenty balloons inflated with hydrogen. Now as we rise upward in the air the electric potential increases rapidly, and if a conducting body at a height gives off water drops or products of combustion, it is rapidly brought to the potential of the air at the place where it is. In the case of Zeppelins this equalization is, no doubt, brought about by the escape of products of combustion produced by the engines. When the conducting body is brought down suddenly to earth again, there may be a great difference of potential between it and the objects on the earth. If it is a good conductor, a spark may pass, and if it is, as in the case of a Zeppelin, a conducting body containing a highly inflammable gas, leakage of which cannot altogether be prevented, this spark may cause an explosion and destruction of the airship. Again, the violent electric oscillations created in all metal objects near powerful radiotelegraphic apparatus may cause sparks to jump between metal parts, and hence may inflame a hydrogen leak.

It has, therefore, been recognized that there are special electric difficulties in connection with the working of wireless on rigid airships with metal frames and also in connection with the use of spark apparatus. However carefully the actual working spark is inclosed, there is always risk of induced sparks.

There is room, therefore, yet for much research and experimenting in connection with the use of wireless telegraphy on aeroplanes and airships, and the practical problems are by no means completely solved.

It is beyond any doubt that this war is a war of engineers and chemists quite as much as of soldiers.

The 42-centimeter Krupp gun which smashed, in a few days, the fortifications of Liege, Namur, and Antwerp, which were confidently expected to hold out for months, is only a piece of heavy engineering. The complete gun weighs 87 tons, and the foundations or carriage, 37 tons. Two hundred men are necessary to erect and work each gun, which requires twelve railway wagons for its transport and is composed of 172 parts. It takes twenty-five to twenty-six hours to erect in place. The projectile or shell weighs 8 hundredweight, and is 5 feet 4 inches long and 16½ inches diameter. It is fired electrically from a distance of about a quarter of a mile, and each shot costs £550. The range at which the Liege forts were destroyed was 14 miles. The mere transport and erection of this gun, let alone its manufacture, demands engineering knowledge of a special kind. It is the same with smaller arms. The rifle, except as a support for a bayonet, has almost become obsolete in face of the machine gun.

To win this war we have to achieve engineering feats. The mammoth howitzer, the great armored triple-engined aeroplane, and the quick-firing machine guns are all products of the engineer's workshop, and the pivot around which all Germany's maleficent power turns is Krupp's works at Essen and the chemical and ammunition factories in Westphalia. The knockout blow will be given at those points, and they must be reached through the air if trench work proves too slow.

But in addition to the concentration of engineering knowledge and skill on the problems of the war, we have to think as well of what will come after. What is required is not merely opinions on inventions already made, but the proper organization of inventive power and scientific research to bring about new and useful results. This is only to be achieved by bringing to bear adequate combined inventive or scientific power on definite problems which are not too far removed from practical possibilities.

We have as yet made scarcely any progress in the creation of a disciplined army of scientific workers which shall embrace all the abilities in the Empire. We are still in the stage which by comparison with an army is that of a mob of civilians equipped for war with shot guns and sticks.

One reason for this, I think, is because our chief scientific body, the Royal Society, has not taken upon itself more the function of guiding and assisting the general direction of research and invention.

The real function of the Royal Society should be to organize, direct, influence, assist, and promote scientific research, and to do it by an efficient organization embracing the whole of its fellows. It represents, or should represent, the very best ability in all departments of scientific knowledge, and it should be organized into grand committees of subjects, as suggested by Prof. Armstrong, on one or more of which every fellow should have his place. The work of these grand committees should be to guide and instigate research in their own departments, to organize general discussions on leading questions in the manner undertaken of late years by the British Association, and to help to direct toward common and important ends the powers of scientific investigation in our universities and colleges.

The special and technical societies provide the facilities required for the reading of papers. A paper on physics, chemistry, or engineering, as a rule, receives better discussion and criticism if read at the Physical, Chemical, or Engineering societies than at the Royal Society, and the discussion on a paper, if proper time and notice are given, is often quite as valuable as the paper itself. Although the individualistic method of research in which each scientific worker takes up whatever kind of research he pleases has produced good results in the past and is in agreement with our national characteristics, it is a serious question whether we shall not have to put limits to it in the future. The problems which await solution require, in many cases, combined or co-operative research. One of the most useful improvements in the proceedings of our learned societies would be the devotion of more time to well-organized and predetermined subjects of debate with the object of advancing knowledge at the boundaries of cognate sciences.

This applies to the purely scientific problems, as well as to the problems of industrial research. It must be remembered that after this war is over in a military sense we shall immediately commence another war of a different kind, in which the weapons will not be bullets and shells, but our national powers of invention, scientific research, commercial organization, manufacturing capabilities, and education, and these will be pitted against those of a highly organized Germany determined to win back in commerce by any and every means, fair or foul, that which has been lost in war.

That commercial and industrial war will be waged by our enemies with the same ruthlessness and neglect of all scruples as their military operations. We have said good-bye now and forever to those easy-going amateur British methods which have held us in the past. What we require is to obtain a higher percentage efficiency in all our operations. We have to attain larger and better results in education, scientific research, and industrial work to increase our national output in every way.

We have been buying dyes, chemicals, optical instruments, and drugs from Germany, glass from Austria, arc light carbons, electric machinery, and a hundred other things we have no need to buy, and the reason is that we have been shirking the effort and research necessary to make them as cheaply or as well at home. But the England with a national debt of 2,000 to 3,000 millions sterling will be a different kind of place to live in from the England of the year before last, and we shall have to adapt ourselves to the new conditions by new methods of work.

One of the most important of these, I venture to think, is the extension of co-operative research, both scientific and industrial. In the case of industrial work manufacturers are afraid of making their wants and difficulties known lest the mere statement of them should enable a British rival to find a solution and get ahead. It is necessary to appreciate, however, that rivalry between British manufacturers is not nearly such a serious matter as the competition of Germany with all of them will become, and that British manufacturers will have to stand shoulder to shoulder to meet the common foe. German firms do not hesitate to pool their knowledge if it enables Germany to get ahead of other nations, and British trades will therefore have to meet this organization by one of a similar kind. In the same manner I have long been convinced that far greater advances might be made in purely scientific research in many departments of knowledge if we were to adopt more extensively the custom of associated work. I mean by this the formation of committees of workers, not too large for expeditious decisions, but charged with the duty of investigating certain formulated problems. It is in this respect that our learned societies might do so much more than they do. The proceedings of these societies are mostly a record of isolated, disconnected pieces of work of very different scientific value. But if properly organized discussion were brought to bear on the question, it would be possible to induce investigators of reputation and ability to associate themselves more in conjoint work to the great advantage of our common knowledge. The learned societies should therefore fulfill to the adult and experienced investigator the same function which the professor or teacher should fulfill to his research students, viz., supply them with suggestions for lines of research to stimulate thought and invention.

It is quite certain that we shall have to organize in this way to a far higher degree than we have yet done what may be called the strategy of research, and that the learned societies should act in some capacity like the great general staff of an army toward the subordinate generals and corps commanders. We require therefore to get on to the councils of our learned and technical societies and into their presidential chairs not merely men eminent for their private researches, but men of large ideas with organizing abilities and inspirational power. If we do not do this, then, although by a lavish sacrifice of life and treasure we may win, as we are determined to do, in the military and naval operations, we shall in the long run be hopelessly defeated in that slower but none the less deadly scientific and commercial competition which will follow upon the cessation of actual hostilities.

Depth of Projectiles.—A new method of locating the depth in the tissue of a foreign body, such as a bullet, has been devised. The instrument used is a radiographic stereoscope, and by the angle indicated in the photographs made with it, indicates the location of the bullet.

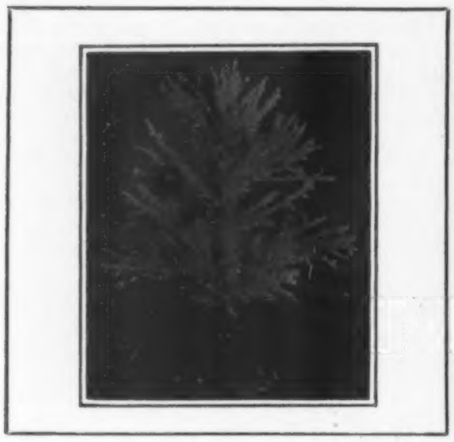


Fig. 1.—Lead.

Fig. 2.—Lead.

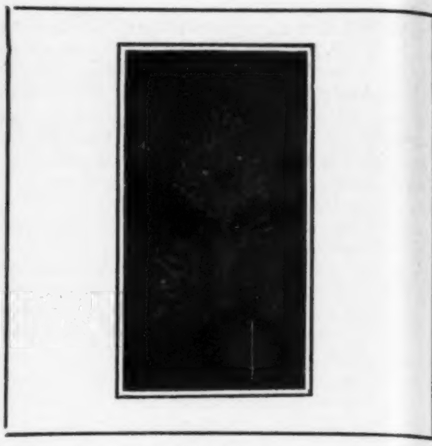


Fig. 3.—Lead.

Motion Pictures of Electrolysis

A Valuable Aid in Scientific Investigation

A German firm has been making motion pictures of electrolysis by a method which is described in a recent issue of the *Elektrochemische Zeitschrift*, from which the accompanying illustrations are reproduced.

Solutions of various metals were electrolyzed in narrow glass vessels with plane sides, in front of a dark background. The growth of the deposit on the electrodes was photographed by a motion picture camera, the strength of the current being regulated by interposed resistance so as to make the pictures as impressive as possible. The scale was between that of ordinary motion pictures and that of microphotographs, and hence the phenomena are very highly magnified in the projected pictures. The following metals were deposited:

Fig. 4.—Zinc.

1. Lead from its acetate (Figs. 1 to 3). In this case a cylindrical electrode was used and the familiar "lead tree" was formed at its tip. Some smaller growths, separated from the main deposit by a bare strip of the electrode, also appeared. The growth was so rapid that a long film could be obtained in a short time, but the fine branches were broken off by their own weight when they had attained a certain length.

2. Mercury from its chloride. Here it was possible to record on the film the process of amalgamation as well as that of deposition. The operation could not be continued very long, as the solution was made turbid by the amalgam.

3. Zinc from its chloride. Very fine results were obtained with this solution. Fig. 4 shows the deposit at its maximum beauty, while Fig. 5 illustrates the re-solution of the deposit by a reversal of the current.

4. Silver from its nitrate (Figs. 6 to 8). These pictures require no explanation. They illustrate the tendency of silver to be deposited in filaments, which by their superposition finally produce a dense cohesive deposit.

5. Tin from its choloride (Figs. 9 to 11). These pictures require no comment.

What value have motion pictures of this sort? In the first place, they combine the advantages of ordinary motion pictures and microphotographs. While the single microphotograph records only a single instantaneous phase of a continuous process, the motion picture film reproduces every phase in its proper sequence. It would be difficult to gain a comprehensive view of the process of electrolysis from a large number of detached microphotographs. The succession of the individual phases and the course of the process can be followed only by means of projected motion pictures.

Films of this sort will be very valuable to teachers. Our illustrations reproduce only two or three instantaneous pictures from each film. The whole film, when projected, shows the crystals of metals shooting out, the deposit growing and assuming characteristic forms —in short, a living picture of the process of electrolysis.

Such films may also be useful in research. For this purpose the object will be, not to produce striking and characteristic pictures, but to explain otherwise inexplicable phenomena, such as the sudden variations in

Fig. 5.—Zinc.

Fig. 6.—Silver.

Fig. 7.—Silver.

Fig. 8.—Silver.

Fig. 9.—Tin.

Fig. 10.—Tin.

Fig. 11.—Tin.

current and resistance, re-solution and lamination of deposits, etc., which sometimes take place. If it shall be found possible to obtain, by motion pictures, simultaneous records of the processes going on in the electrolytic cell and the indication of the measuring instruments, the explanation of these phenomena may be found. The reactions and other processes that occur in the electrolysis of organic compounds may possibly be elucidated in the same way.

Surface Tension Due to Intermolecular Attraction*

And Surface Tension Due to Molecular Direction Force in Liquid Crystals

By O. Lehmann, Professor of Physics at the Technical High School of Karlsruhe

An ordinary drop of liquid tends after any distortion to assume spherical shape on account of surface tension due to the mutual attraction between molecules; liquid crystals, on the contrary, tend to assume polyhedric forms, like solid crystals.

The undiscovered cause of the departure of liquid crystals from the spherical form I have previously termed "form-determining force" (Gestaltungskraft).

For a long time I regarded this form-determining force as the resultant of thermic motion and mutual attraction of molecules; but the latest researches have shown that molecular directive force is probably the most important factor.

Molecular directive force may be represented as the working of a molecular astatic magnet system. In case of ordinary isatropic liquids it is too weak to aid cohesion by bringing about parallel arrangement. Its contributions to cohesion in the case of anisotropic fluids is also negligible. Mutual attractions between molecules is the real cause of cohesion, hence the real cause of surface tension is liquid crystals.

In the case of drop-like liquid crystals the variety of surface tension due to mutual attraction is the only one to be considered. Such a crystal drop takes on perfect spherical form, and the surface tension is everywhere the same.

The case of the ordinary liquid crystal is different; here, to the surface tension originated by molecular attraction is added the surface tension due to molecular directive force.

Let us suppose, for the sake of clearness, that the former is not present, and that there exist only those forces which the members of an astatic magnet system exert on one another; then the system of molecules shown in Fig. 1 would roughly correspond to a tetragonal crystal; the opposite poles of the magnets are as closely approximated as possible; the surface tension is, therefore, at a minimum. Were, however, the surface conditions those shown in Fig. 2, then repellent forces would predominate at the surface, and the surface tension would be expansile rather than contractile. Imagine the corners of Fig. 1 cut off so that they would show the structure of Fig. 2: equilibrium would be destroyed and streaming would occur, which would result in filling out again the cut corners; which theory accords with that of "spontaneous homöotropy." Molecular directive force is thus seen to be the chief cause of polyhedric form. Although it creates a sort of capillary pressure tending to blunt edges and corners, this blunting does not occur because instantly new and opposing forces of greater strength would be awakened.

Such blunting is possible when to the surface tension of directive force is added the surface tension of molecular attraction, whose effect can be likened to that of a bounding membrance of uniform tension. How far this will be effective in rounding corners and edges, will depend upon the strength in comparison with that of the molecular directive force.

The effect of these two surface tensions on the distortion of liquid crystals is best seen by imagining that they do not exist.

Imagine the space beyond the liquid crystal filled to a great distance with the same kind of liquid crystaline substance; then the surface tension ceases to exist. It is easy to imagine damming up or rotation brought about by whirling as Fig. 3 indicates. The two upper points indicate the cross-section of a circular eddy; the two lower show rotation in the opposite direction. If by particles of coloring matter a cylindrical portion *ABCD* be distinguished from the mass, then by variation in the rapidity of streaming, the form of this cylinder can be stretched to that of *EFGH*. The parts of the surface designated 1, 2, 3—*a*, *b*, *c*, come into the similarly designated portions of the elongated cylinder. Since, however, the middle portions must remain the same, displacements and distortions are inevitable, which, were the medium solid, and the effect of the forces which the streaming occasions not in excess of the limit of elasticity, must arouse an elastic counter force. This cannot occur because of spontaneous homöotropy. The work necessary to produce distortion is then entirely dependent on internal friction.

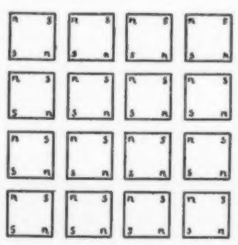


Fig. 1.

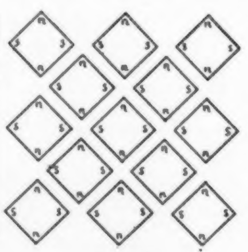


Fig. 2.

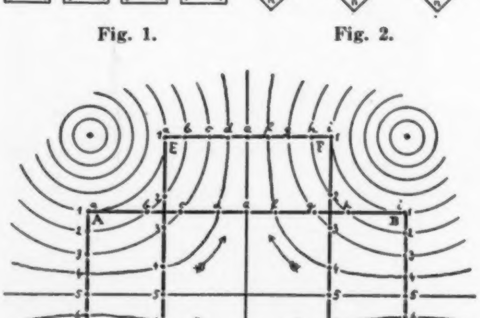


Fig. 3.

Should we now remove this complementary medium, leaving only the cylinder *ABCD*, then the edges would be rounded by surface tension and spontaneous streaming would occur, producing distortion until the resultant of the two surface tensions had reached a minimum.

I have previously stated my theory that the form of liquid crystals is determined by molecular directive force. The expression of this theory is rendered clearer and more precise by the conception of a surface tension due to molecular directive force.

*Translated for the Scientific American Supplement from the Verhandlungen der Deutschen Physikalischen Gesellschaft xiv Zahlingang No. 10.

Saws and Other Tools of Non-Rusting Alloys

A series of alloys of cobalt, chromium and iron, with low carbon content, containing about 20 per cent of chromium, and in which the iron content has been gradually increased from 10 per cent to 75 per cent, has been prepared by Elwood Haynes of Kokomo, Ind. Such alloys are claimed to show little variation in either chemical or physical properties so long as they contain 5 per cent or more of cobalt and from 20 to 25 per cent of chromium. They are all readily malleable at a bright red heat and can be worked into sheets or rods from cast ingots without difficulty. These alloys receive and retain a luster and are much less subject to oxidation or other changes in the atmosphere than the binary alloys of iron and chromium alloy.

Such alloys, containing a constant percentage of chromium (20 per cent) and varying from 5 to 75 per cent in iron (at intervals of 10 per cent) and from 70 to 5 per cent in cobalt, made into bars, ground smooth and covered with a strong solution of ammonium chloride, failed to show the slightest stain or tarnish after several days. While they are distinctly softer than those of cobalt and chromium, covered by previous patents, they have the peculiar advantage of being incorporated into saws, boring tools, etc., which possess sufficient hardness for wood-working tools. They can also be worked almost as readily by the file as similar steel implements.

Tools of some of these alloys are represented as hard enough to permit easy working of wood, bone, ivory or soft metals, and are easily sharpened at ordinary temperatures; knife blades, saws, etc., may be given their shape and edge during working and the edge will be retained on cooling.—*The Iron Age.*

The Electric Locomotive*

Its Operation and Rating as Compared With Steam

By A. H. Armstrong, Assistant Engineer, Railway and Traction Department, General Electric Company

THE present article touches upon the subject of electric locomotive operation, what excuse it has for existence, and draws some few comparisons with the steam locomotive as to its selection and rating.

Commencing with the New York Central locomotive, we have a distinctive type admirably adapted to high speed passenger service. It is designed to deliver a moderate tractive effort at a high speed, the first 47 locomotives of the "S" type giving a tractive effort of 7,100 pounds continuously at a speed of 56 miles per hour and a one-hour rating of 20,600 pounds. The driving motors, four in number, are thus able to give an output of 2,200 horse-power for a period of one hour without overheating. The later "T" type of locomotive, weighing approximately 130 tons, has a capacity of 14,000 pounds tractive effort at a speed of 53½ miles per hour, or a continuous motor capacity of approximately 2,000 horse-power. For the one-hour period the output is 2,600 horse-power.

Electric railway engineers talk about continuous and one-hour capacities and also about starting tractive effort, and that brings up one point that needs explanation to the steam railroad man; that is, the time element plays a very important part in the determination of the rating of an electric motor. In a steam locomotive the tractive effort or pulling power is determined by the diameter of the piston and the steam pressure behind it, and the locomotive can deliver this tractive effort continuously provided it has sufficient boiler capacity to supply the quantity of steam demanded and the fireman is sufficiently industrious to keep the grate covered, which is supposed to have sufficient surface. With the electric locomotive, on the contrary, allowance must be made for the fact that the insulation used deteriorates if heated continuously above a certain amount. It takes a considerable time for the motor to heat up to this dangerous point, thus giving rise to a momentary rating or starting effort, a one-hour rating and a continuous rating, the latter being the output which the motors can give continuously without injurious heating. In other words, the steam locomotive engineer is concerned in keeping his boiler hot, while the effort of the designer of electric locomotives is to keep his machine cool.

In the early electric locomotive design there was no such thing as continuous rating. The service which it was called upon to perform was of an intermittent character, the runs between stops were short and the designing engineers were concerned mostly with the question of starting or accelerating, tractive effort and commutation. Therefore, the continuous rating of the early motor did not affect its design. With the extension of electrified lines, and more especially with the introduction of the electric locomotive on main steam trunk lines, it was found that the motive power was called upon to deliver a continuous output for long periods at a time, and it became necessary to introduce air blown or ventilated motors as well as fire-proof insulation in order to secure the large output required without exceeding the limitations of space and weight imposed by standard gage and reasonable diameter of wheels, wheel-base and weight per driving wheel. We are, therefore, designing electric locomotives to-day suitable for the heaviest class of freight and passenger service. Such locomotives are entering into competition with the steam locomotive with a full appreciation of the phenomenal growth and possibilities of the latter as developed during the past few years, as well as a knowledge of the growth in the demands placed upon the motive power to take care of modern high-speed passenger and freight train service.

In designing such electric locomotives the electrical engineer is fully alive to the fact that a steam locomotive has been built weighing 750,000 pounds on drivers and having a total weight of 850,000 pounds, and that nearly 90 per cent of the total weight of the locomotive and tender is now rendered available for tractive purposes by the development of the Mallet principle to include cylinders placed upon the tender itself. It is also known that the tractive effort of these locomotives has increased from the 40,000 pounds of the early "Consolidation" engines weighing 200,000 pounds on the drivers, to values as high as 160,000 pounds for the latest type of Mallet. It is also known that the introduction of the steel passenger car with the need of high sustained speeds of between 60 and 70 miles per hour, calls for the hauling of passenger trains weighing over 1,000 tons, and that provision is made in the latest New York Central electric locomotive to take care of 1,200 tons at 60 miles an hour. Due appreciation is also paid to the results secured with the combination of superheating and simple engine which has so largely replaced the compound. Also the increased capacity afforded by the use of mechanical pushers, and fire door openings with hand firing, have increased the efficiency of the fireman so that it is now possible for him to throw between 5,000 and 6,000 pounds of coal per hour where previously 4,000 pounds might be considered good performance. Finally it is fully understood that the modern steam locomotive has been so improved as to fuel economy by the introduction of superheating, fire arch and other developments that it is possible to get an indicated horse-power with a consumption of 15 pounds of steam and less than 2 pounds of coal under the best conditions of operation, and that with the use of mechanical stokers or with oil-fired boilers, locomotives are in operation, giving 3,000 indicated horse-power or more.

Fully appreciating the above facts and the magnitude of the problem confronting him, the electric railway engineer nevertheless offers in the modern electric locomotive a type of motive power which can accomplish results in transportation which are not possible to obtain with the steam locomotive as regards tonnage handled, speed on mountain grades and general flexibility and economy in operation. The first large locomotive built was placed in operation on the Baltimore & Ohio Railway in 1895, and it is worthy of note that this was a gearless locomotive and a forerunner of the highly efficient gearless locomotives now in operation upon the New York Central road to-day. The New York Central locomotive, as developed in the later "T" type, is capable of hauling the heaviest overland passenger trains over any length of track that may be electrically equipped, and withal at a cost for upkeep, including all labor and material spent in maintenance, of not exceeding 3½ cents per mile run, as is shown by the records of the New York Central during the operation of the past seven years.

The first railroad in this country to adopt electric freight locomotives having large sustained output capacity is the Butte, Anaconda & Pacific Railway. Some three years ago the construction of 92 miles of the total of 114 miles of track was commenced, being completed for freight operation in May of 1913 and for complete freight and passenger operation in October of 1913. There are still four or five steam engines in operation on Butte Hill, but these will be replaced in the near future, so that in a short time the entire road, or 114 miles of track, will be in operation electrically. The one motive inspiring this installation was economy in operation, and preliminary reports indicated that the savings in electric over steam operation should be sufficient to pay something like 18½ per cent upon the capital required to electrify. During the first six months of operation of this road careful detail figures were kept on the cost of electric operation, every item of expense being accounted for, with the result that prorated over the entire fiscal year there was a saving shown of $240,000 over the cost of steam operation during the previous year with practically the same tonnage handled. The entire first cost of this installation, including all material and labor and contingent expenses as well as interest on money during construction, was approximately $1,200,000, so that the saving above indicated results in a 20 per cent gross return upon the capital required for electrification. This makes no allowance for the scrap value of more than 20 steam locomotives discarded.

On this road the heaviest class of freight trains are operated electrically, regular operation calling for the movement of from 3,500 to 4,000 tons behind the locomotives from the Butte Yards to Anaconda, and record has been made of train weights as high as 4,500 tons trailing against a gradient of 0.3 per cent. Each locomotive weighs 80 tons, all on drivers, and two such units are coupled together, operated by one engineer and comprise a complete locomotive hauling the above tonnage. At the Butte end there is a gradient of 2½ per cent against the returning empty cars, and at Anaconda a 1.1 per cent grade against which one of the above locomotives hauls 25 cars, or approximately 2,000 tons.

This leads up to the subject of the rating of an electric locomotive. The Butte locomotive, weighing 80 tons, all on drivers, will give a continuous tractive effort of 26,000 pounds at a speed of approximately 16½ miles per hour at full substation line voltage. This corresponds to 16¼ per cent of the weight upon the drivers. Investigation of the locomotive loading regulations of many steam roads operating over ruling grades indicates that it is almost universal practice to assign to a locomotive a trailing load so that the tractive effort at the rim of the drivers, as required on a ruling grade, will be equivalent to approximately 18 to 19 per cent of the weight upon the drivers. In other words, from 18 to 19 per cent coefficient of adhesion between driver and rail is now considered good steam practice, and the electric locomotive rating is closely following this same steam practice. The electric motor, of course, gives a perfectly uniform rotation to the driving wheels, and should thus give something like 10 per cent more tractive effort than the steam locomotive with its reciprocating parts. Continued operation will develop whether this additional 10 per cent tractive effort can be utilized or not. In the meantime steam practice is being followed in the loading of electric locomotives.

In adopting a coefficient of adhesion of 18 or 19 per cent as the basis of determining the tractive effort required on ruling grades, it is evident that there is left for starting purposes the difference between the above coefficient of adhesion and the slipping point of the wheels, whatever that may be, as determined by the condition of the track. Tests on electric locomotives have shown a coefficient of adhesion as high as 35 per cent, or even more under specially favorable conditions, but it is fair to assume a maximum of 30 per cent as available in operation and even 25 per cent may be nearer the average. There is therefore not much difference between the tractive effort required on ruling grades and that required for starting, and in order to be "fool proof" and capable of meeting the exacting demands of the heaviest kind of service, the electric locomotive should be capable of delivering continuously a tractive effort equal to from 16 to 18 per cent coefficient of adhesion of the weight upon its drivers. The Butte locomotive is therefore rated at 26,000 pounds, or 16.25 coefficient of adhesion, as its continuous output, and this capacity is sufficient to meet all demands of operation on the Butte, Anaconda & Pacific Railway.

Coming now to the latest type of trunk line electric locomotive, the one designed by the General Electric Company for the Chicago, Milwaukee & St. Paul Railway, this is a direct development of the Butte, Anaconda & Pacific both as to type of locomotive and general system of electrification installed. The weight of the locomotive is 260 tons, of which 400,000 pounds are on the drivers. Each of the eight driving motors has a continuous rating of approximately 400 horse-power, making the sustained continuous output of the complete locomotive 3,200 horse-power at the rim of the drivers. This locomotive, however, will give a considerably larger output for short periods. For example, it has a capacity of 3,600 horse-power for one hour and even greater than this for short periods. The sustained tractive effort is 72,000 pounds at a speed of 15¾ miles per hour at full substation line potential. Compare this with the Mallet engine of approximately the same weight now in operation on the St. Paul road and we find that the Mallet has 76,200 pounds tractive effort, corresponding to 23.5 per cent coefficient of adhesion, but those of you familiar with the performance of this beast of burden know that it toils painfully at speeds seldom exceeding 7 to 10 miles per hour when operating at its full hauling capacity. It is in this matter of higher speed for the same tractive power that the electric locomotive excels. In fact, the question of speed is simply one of cost and expediency, as the horse-power output of the electric locomotive can be raised to any value desired without exceeding the limits of track loading.

The St. Paul locomotive, weighing 260 tons, has a capacity to haul a 2,500-ton trailing load behind the locomotive on a 1 per cent grade at nearly 16 miles per hour without any assisting locomotive. The St. Paul road in Montana and Idaho crosses three mountain ranges, the Belt Mountains, the Rocky Mountains and the Bitter Root Mountains. From Lombard to Summit, in the Belt Mountains, a distance of 49 miles, there is an average gradient of 0.71 per cent and a ruling grade of one per cent against which one locomotive will haul a trailing load of 2,500 tons without assistance. Between Piedmont and Donald, a distance of 22 miles to the summit of the Rocky Mountains, there exists a

* *The General Electric Review.*

2 per cent grade against which two locomotives will haul 2,500 tons trailing, the second locomotive being used at the rear of the train as a pusher. A second pusher division exists in crossing the Bitter Root Mountains of Idaho, making only two pusher divisions in the 440 miles of electrified road from Avery, Idaho, to Harlowton, Montana.

The general design of the St. Paul locomotives comprises a locomotive divided in halves for facility in shop repairs, each half being identical and equipped with four driving axles and two guiding axles. The design is identical with the Butte locomotive except for the addition of the four-wheel guiding truck at each end of the locomotive, one of the reasons for its introduction being that the same locomotive is thus made available for both passenger and freight service. This does not mean that any locomotive can be used interchangeably at will in both freight and passenger service, but it does mean that all parts of the locomotive are identical whether used for freight or passenger service with the single exception of the gearing between motors and driving axles which has a ratio of 4.56 for freight service and 2.45 for passenger service. This adoption of a uniform type of motive power for all classes of service should result in effecting a great reduction in the cost of maintaining the locomotives of the four engine divisions electrified.

A second type of light locomotive for shifting service may be introduced later, although in this connection arrangements are being made to operate independently, one half of the locomotive being equipped with draft gear in place of the articulated joint joining the two halves. This will provide a locomotive weighing 130 tons having 200,000 pounds on the drivers and capable of doing one half the work stated above as the capacity of the combined locomotive; this half locomotive would require turning if used in passenger service, as it has guiding axles at one end only.

The installation on the St. Paul road will use for the first time on such a large scale a principle which should be of the greatest advantage in the operation of mountain grade divisions; that is, the utilization of the motors on the locomotives to brake the train on down grades and return the energy of the descending train back into the trolley. The efficiency of the locomotive, both electrical and mechanical, is nearly 90 per cent as a maximum, not taking into account the minor losses in driving ventilating fans and air compressors. When descending heavy grades, therefore, the reversible feature of the locomotive, permitting it to transform mechanical power received into electrical energy, suggests by this means a considerable reduction in the amount of power required to operate the road. It is probable, however, that a power saving of less than 10 per cent will result from the regenerative braking feature of the electric locomotives, and the principal advantage resulting from the introduction of the electric brakes will be to relieve the brake shoes and wheels from the dangers attending overheating. To those of you who are familiar with the handling of trains on long and heavy down grades this argument will appeal in full force, as it is not an uncommon sight to see brake shoes red hot as a result of sustained application on down grades of long extent.

In conclusion it is well to comment on the suitability of the New York Central gearless type of locomotive for passenger service. This is seen very plainly when the entire absence of mechanical losses in the motor other than the brush friction on the commutator is considered. There are no bearings on the motor of any kind as the armature is mounted directly upon the driving axle and the field structure is part of the frame which is carried upon the journals. The electrical efficiency of the motor and the frictional losses on the commutator, due to the brushes, are therefore the only losses to be considered, and the efficiency of this locomotive in operation is therefore between 93 and 94 per cent. In other words, of the electrical input received at the third rail shoes, from 93 to 94 per cent appears as useful mechanical output at the rim of the drivers. This in itself is a most remarkable performance, but the value of this high efficiency locomotive is rendered more important when it is explained that the maximum efficiency occurs at approximately the free running speed between 50 and 60 miles per hour. In other words, the motor has a drooping efficiency curve, being highest at free running and lowest at overloads or during acceleration, and in this respect being just the reverse of the efficiency curve of geared motors which reach their highest point at practically the one hour load capacity of the motors. The gearless locomotive is therefore particularly adapted to operate on fairly level profiles and could not be utilized to such great advantage on roads like the St. Paul, which contains many heavy grades sustained over a long distance. It is very difficult to combine in one structure motors capable of hauling 800 tons trailing over heavy sustained grades, and also have the characteristics required for good operation on level track at 60 miles per hour, and in the St. Paul locomotives recourse to gearing between motor and driving axle appears necessary to secure the greatest all round advantages at the lowest first cost.

A Burning Oil Well

And the Well That Extinguished Itself

It is a common occurrence in the oil fields for a spouting well to become ignited, and then there is serious trouble, for it is often months before the fire can be extinguished, and the flow of oil or gas controlled. The reason for this is the great pressure under which the oil is forced out, a pressure that sometimes defies the strongest constructions that can be devised. There was a case some years ago in Mexico where what was claimed to be the largest oil well in the world became uncontrollable and has never been subdued. So great was the pressure in the well that the heaviest castings used in an endeavor to control it were hurled into the air, and for forty days the flames from the burning oil shot up 1800 feet in the air. In a short time the original 18-inch hole developed into a huge crater from which great volumes of salt water are still flowing.

The owners of the well shown in the illustration on the first page of this issue were much more fortunate. This well is located at Whittier, Cal., and when a depth of 3,900 feet had been reached it showed a pressure of 600 pounds to the square inch, even with a 4-inch valve open. Suddenly something gave way, and the tools were shot high into the air, to be followed by a rush of oil and gas. The flying debris broke an electric light wire which fired the oil, and a flame over 200 feet high was the result, as seen in the picture, which is from a photograph taken by Charles A. Waer. The explosion took place at 8.30 in the evening of September 28th, and the flames burned with a great roar all night; but about half past four in the morning great jets of water began to shoot from the well, and one particularly violent geyser extinguished the flames. Although the well was still spouting preparations were at once begun for capping the well, and fixtures and valves capable of withstanding a pressure of 2,000 pounds were provided, to be put into place at the first favorable opportunity.

It may interest photographers to know that this picture was the result of a half minute exposure on an ordinary film, with a lens opening of f8. Many other photographers who attempted instantaneous exposures, being deceived by the brightness of the flames, met with complete failure.

Lime and Portland Cement

Although Portland cement gives a strong mortar, it is not very satisfactory for such purposes, because its lack of plasticity makes it rather difficult to work. It has been found that the addition of small quantities of hydrated lime will increase the plasticity without material injury to the other properties of the mortar.

If a cement mortar is sufficiently rich in cement, and the surface is well troweled, it can be made practically waterproof.[1] Unfortunately, the working qualities of of the material are such that it is difficult to get a laborer to trowel it sufficiently. The addition of hydrated lime increases the plasticity of the mortar, so that troweling does not entail so much work. Moreover, the particles of hydrated lime are fine in comparison with the cement and sand, and therefore tend to fill up the voids and produce a denser mortar. For these reasons hydrated lime is looked upon as a waterproofing material.[2]

The use of hydrated lime for this purpose brought about a demand for information toward which a number of investigators have been working. Their conclusions may be summarized as follows: (1) The magnesia in a magnesian hydrate does not act the same as magnesia in the cement itself, but a mixture of cement and magnesian hydrate is stronger at the end of a year than a similar mixture containing high-calcium hydrate.[3] (2) A series of tests made by the Bureau of Standards indicates that cement can be replaced by hydrated lime without material diminution of strength if the ratio of hydrate to cement is less than 1 to 3 by weight. Of course, this conclusion can be applied only to the particular cement used, and it must be noted that the mortars tested were of unusually thin consistency.[4] (3) Mortars containing hydrated lime in the proportions of 1 to 3 or less harden better under water than when exposed to air, and some investigators therefore believe it safe to recommend the addition of hydrated lime to cement used for road material or for foundation work.[5] —*Mineral Resources U. S., Part II, U. S. Geological Survey.*

[1] Wig, R. J., and Bates, P. H., Tests of the absorptive and permeable properties of Portland cement mortars and concretes: Bur. Standards Tech. Paper No. 3, 1912.

[2] Lazell, E. W., *Concrete-Cement Age*, March, 1914, p. 130.

[3] Lazell, E. W., Tests of cement-lime mortars: Nat. Lime Mfrs. Assoc. Trans., 1911.

[4] Emley, W. E., Hydrated lime in a Portland cement mortar: Nat. Lime Mfrs. Assoc. Trans., 1914.

[5] Spackman, H. S., Effect of hydrated lime on change in volume and strength of mortars and concretes: Nat. Lime Mfrs. Assoc. Trans., 1914; *Concrete-Cement Age*, March, 1914, p. 112.

Power House Accounts

The managers of many large manufacturing plants have become convinced of the advantages resulting from producing the entire power, light and heat required at their own establishment, but to realize the full advantage of the system there should be a proper system of bookkeeping.

Discussing this point a writer in the *General Electric Review* has the following to say:

The power house should be isolated, it should always be ready to supply power, light, and heat, and be ready for overloads; but, it should sell these commodities to the factory. No man can run a power house efficiently unless he either has control of the power, light, and heat when it leaves the power-station or can send a monthly bill of them to the factory. When the superintendent receives these bills—so much for "power," "heat," and "light,"—he will give them attention and will issue instructions for repairs or renewals which will effect a saving wherever possible in order to lower the expenses of his manufacture.

This satisfactory method of billing can be put into practice through the use of steam flow meters. The power house staff can determine (by a series of readings from the power and the light steam flow meters, which should be separate) the price to charge per kilowatt-hour for power and for light. The amount of steam that is used in the factory can be arrived at by placing a recording and integrating steam flow meter in the steam lines. The cost can be determined and a fair rate charged per thousand pounds of steam used, to insure that there will be no waste of steam through leaky steam traps, or by exhausting into rivers, creeks, or sewers. The amount of return condensate should be registered and if it is not up to normal the factory should be penalized by charging a small percentage more for power, light, or heat, or some immediate arrangement can be entered into with the superintendent or the master mechanic to have the matter remedied. Too often the loss is blamed on the generating apparatus and operating engineers instead of on the carelessness and waste of the factory.

Toughening Filter Papers

A paper in the *Chemical News* by Dr. Clayton Beadle on the toughening of filter papers describes a very useful and simple method of strengthening a filter paper to such an extent that it will withstand the pressure produced by a powerful filter pump. The paper is folded and fitted into a dry funnel in the ordinary way, and then a few drops of nitric acid of specific gravity 1.42 are allowed to fall in the apex of the paper cone. The funnel is canted and quickly rotated so as to saturate the free unsupported apex of the cone with the acid, and is then immediately rinsed out under a tap, being filled and emptied from the top repeatedly, and finally rinsed out with distilled water if the presence of tap water is undesirable. This treatment does not slow the filtering action of the paper; on the contrary, it tends to accelerate it, though treating the paper similarly all over slows the filtering very considerably four or five times. The method is credited to Mr. E. J. Bevan, about thirty years ago, but few people seem to know of it.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Balloons at the Siege of Paris

To the Editor of the Scientific American Supplement:

In connection with the excellent table and charts on the "Use of Balloons During the Siege of Paris in 1870-71," which you published in your issue of October 9th, it may be of interest to your readers to know that several American citizens participated in those daring ascensions.

The balloon "George Sand," which was launched in Paris on October 7th, 1870, carried in addition to its pilot two Americans, Messrs. May and Raynold, who had been intrusted by the French government with a special mission. These two gentlemen were incidentally the owners of the balloon, and when Paris was being besieged by the Prussians they at once presented it to the French government.

Another *ballon de siège*, "L'Egalité," which left Paris on November 3rd, 1870, and was piloted by Wilfrid de Fonvielle, the noted physicist, carried four Americans, whose names are Bunel, Dubreuil, Rouzé and Villantrois.

Both balloons landed safely in the French lines.

As can be seen from the above, the gallant Americans who are doing such splendid work with the French Air Service in 1914-15 have had their forerunners in 1870-71.

Ladislas d'Orcy.

Fig. 7.—A bull snake. A useful species.

Fig. 5.—Garter snake. Harmless and useful.

Snakes and Their Value to the Agriculturist*

Facts That Should Be Known About Valuable Friends of the Garden

By R. W. Shufeldt

VERY recently one of our western papers gave an account of how a farmer, in one of the townships of Ohio, while plowing on his farm, turned up a snake which escaped him by crawling into a small opening in the ground close to the furrow. Picking up a shovel which happened to be near at hand, he quickly enlarged the opening into which the reptile had disappeared, and had dug but a short distance when he "discovered a small cave occupied by scores of snakes." This blood-curdling sight caused him to call loudly for help, and a small army of neighbors soon assembled for his protection. These latter immediately fell upon the innocent and entirely harmless snakes, and slaughtered, according to the story, 125 of them. They were of the species commonly known as the "blue racer," and the killing of them was an easy matter, notwithstanding the fact that "several of the larger ones showed fight."

Apart from this massacre of the innocents being a brutal and cowardly performance, it is well worth the consideration of the farmer, agriculturist, and poultry-raiser in this country to investigate and ponder upon it. In the first place, is the "blue racer" a venomous and otherwise dangerous snake? Most assuredly not. It is not only a perfectly harmless and innocent reptile, but a very gentle species, and may, with a little kindness and trouble, be easily tamed as a pet. In the Atlantic States we have the genus represented by the common black snake (*Zamenis constrictor*), of which the western form or the blue racer is a sub-species (*Z. c. flaviventris*). Fig. 1 of the present article gives a reproduction of a photograph I made last summer of the common eastern black snake, which was a very large and handsome specimen.

*Photographs from life by the author, with the exception of Fig. 7.

Fig. 1.—The Blue Racer, a harmless and useful reptile.

Fig. 2.—Copperhead.

Fig. 3.—Horned rattlesnake.

These 125 "blue racers," then, were simply a big wad of harmless, inoffensive snakes, rolled up together, awaiting the opening of spring, when they would part company and go off to breed. This particular snake lives, to a very large extent, upon moles and field mice; and had these been allowed to live and lay their eggs, they would probably have been represented by upward of 500 snakes of that species before the year was out.

Now this is a most conservative computation, and, to continue it, it may be said that each of these 500 snakes would be pretty sure to eat a field mouse apiece during the course of a day—that is, the lot would destroy 500 field mice per diem or about 15,000 of these destructive rodents per month. Then when we come to think that the destruction of 15,000 field mice per month probably means the getting rid of some 90,000 of them during the course of the six months of the year, when they are consuming grain or other kinds of produce of the farm, the persons who destroyed those 125 blue racers on an Ohio farm the other day can, if their intelligence admits of it, gain some faint idea as to the amount of harm they did, as compared with the result of their superstitious ignorance and wanton cruelty.

Passing from this incident, it can easily be shown that, as a matter of fact, it would well repay every farmer and agriculturist in the country to keep on his place some five or six harmless, vermin-destroying snakes per acre. It is needless to say that, in proposing such a measure as this, all the venomous species form exceptions to it. No one would be expected to harbor on his premises such reptiles as the copperhead, shown in Fig. 2, or the horned rattlesnake, depicted in Fig. 3, which I photographically copied from the work on the Mexican Boundary Survey, published many years ago.

On the other hand, the blotched king snake, Fig. 4; the garter snakes, Figs. 5 and 6; the bull snake, Fig. 7; and the black snake and its allies, Fig. 1, are all most useful species to be encouraged in this connection, notwithstanding the fact that the last named do destroy a few birds' eggs in the course of a season. Each and all of these several species of harmless snakes, as well as various other kinds, are the natural enemies of rats, mice, weasels, and allied animals, which, from time immemorial, have been the arch pests upon farms all over the country, as well as on the premises of thousands of suburban homes, where are kept various kinds of poultry and other small live stock.

Snakes are especially fatal to the propagation of such animals as I have just mentioned, for the reason that they not only destroy the old ones, but are particularly fond of the young ones. An old, hungry black snake will come along, and should he chance to discover a litter of young field mice in a nest in the barn, or in the corn crib, or out in the meadow somewhere, it is a case of good-bye to that particular family of grain-destroying rodents, for he will make a meal of the entire lot.

Fig. 4.—Blotched King snake—harmless.

Fig. 6.—A family of garter snakes—harmless and useful.

Thousands of harmless snakes are killed all over this country every year by thoughtless boys, ignorant farm-hands, and misinformed women. This senseless slaughter takes place notwithstanding the fact that the United States Department of Agriculture has repeatedly shown, in its valuable published reports, that "to the cereal crops alone in the United States rodents cause an annual loss of $100,000,000."

Think for a moment, then, what an immense saving it would be to our farmers all over the country were they to encourage the protection of the harmless snakes upon their premises, instead of brutally destroying them upon every occasion they chance to meet with them. In time, such encouragement would practically reduce the aforesaid loss to the minimum, or, indeed, doubtless eliminate all such loss, when due to the ravages of the well-known animal pests throughout the country.

There are at least a dozen species of small, harmless snakes that might be introduced to protect our agriculturists against the destruction caused by rats, mice, muskrats, weasels, minks, opossums. Such snakes for example as the common milk snake and the chicken snake would be particularly useful and effective in this connection; and while they are too small to kill the adults of the vermin just enumerated, they are, for the same reason, dangerless with respect to the destruction of the young of the farm fowls of all kinds. On the other hand, they will kill and eat no end of the *young* of the farm pests, and in doing this they will in a short time rid the place of them through the extermination of the various species, at the very outstart of their lives.

Many, indeed the majority, of our farmers believe that the common "chicken snake" haunts his farm-houses and other outbuildings for the sole purpose of feeding upon his young ducks and chickens; whereas, as a matter of fact, this useful snake never does anything of the kind. But it does eat no end of young mice and other rodents in the course of the open season.

This fact can be and has been proven, hundreds of times, by killing and dissecting the digestive system of one of these snakes, shortly after it has had a meal somewhere under the barn or hen-house. Man's dread and hatred of snakes has been, from the earliest time, a matter of erroneous teaching, induced by superstition and false notions about a good many things, all the way from the conversational snake of the Garden of Eden to the misinformed teacher in the class-room of the public school.

Innocuous snakes are the easiest animals in the world to tame, and it is high time that the erroneous ideas about them should be corrected in all educational establishments of every grade. More than this, it should be taught, as is now being done so universally with us in regard to birds, that they are among the best of animal friends that the farmer has about him; and if we destroy them, or perhaps even exterminate them, we are paving the way for the destruction of our forests, or staple farm products, and a good deal else that now and always have been protected by many species of snakes and birds.

The common garter snake, shown in Fig. 6, was a specimen I captured many years ago on the banks of the Hudson River, opposite New York City. It gave birth to sixteen young some weeks after I had kept it as a pet, and in my photograph about half of her brood are in sight. This is a species of harmless snake which feeds upon a variety of vermin, which are the worst pests the agriculturist has to combat every season on his farm; as a matter of fact, the many species and sub-species of this kind of snake destroy unnumbered thousands of young field mice in the country every year that goes by, and by this time the farmer certainly has learned what his enemy, the field mouse, annually costs him.

Animal Venoms and Venomous Animals

Many singular data come to light as a result of the study of serpent venoms, says the *Medical News*. The sting of the Bosnian sand viper causes an ulcer which may become cancerous. Since venoms proceed from glands which are analogous to human salivary glands, it is not surprising to learn that the venomous secretion belongs to the normal digestive fluids. To diminish the number of venomous snakes in a locality the mice, rats, etc., upon which they feed may be exterminated, while animals which prey on snakes may be colonized—the mongoose, hedgehog, hawks, storks, pigs, and even other snakes (constrictors). At the last meeting of the Breslau Medical Society before the war outbreak (*Deutsche medizinische Wochenscrift*, April 15th) Prof. Küttner, the well-known surgeon, cited the above and many other data. Under the old and present nomenclature the lesions due to animal poisons are regarded as purely surgical subjects, because surgical intervention and wound treatment are alike demanded. The advent of snake antisera, new chemical remedies, etc., does not lessen the surgical predominance of treatment. Prof. Küttner states that cupping is of no use, while among chemicals only some of the hypochlorites have any value (potassium, calcium). Constriction of a limb is a valuable resource. Horse serum slightly impregnated with snake venom and Calmette's sera have given some good results, even in advanced cases.

In connection with the subject the *Journal* of the American Medical Association has the following interesting comment on the venom of the rattlesnake:

"Although rattlesnake poisoning has lost most of its former prominence as a cause of death in the United States, the toxic agent itself continues to be a source of scientific interest. Certain points in regard to its action have been debated. Thus it has been asserted[1] that the venom of the rattlesnake is toxic to this species itself. Recently, however, Welker and Marshall[2] of the Robert Hare Chemical Laboratory at the University of Pennsylvania, Philadelphia, have injected the fresh poison obtained directly from the living animal intramuscularly into the same species, *Crotalus adamanteus*, without detecting any untoward effects on the snakes. Rattlesnake serum may be somewhat toxic to certain laboratory animals, but not more so than is the serum of other species. It is said that snake venom exhibits little if any toxicity when it is administered by way of the alimentary canal. This has led to the assumption that the bile exerts antitoxic properties on it. Fraser,[3] for example, believed that snake bile had a marked antitoxic action on the venom—an effect exhibited likewise by ox bile in a less marked degree. Welker and Marshall[2] have found that the bile of the rattlesnake is not highly toxic for pigeons, with which they experimented; but they failed to demonstrate the slightest antitoxic power in this secretion.

Effect of Ultra-Violet Light on the Eyes

The *Electric World* states that cataract is known to be prevalent among glass-blowers, in the tropics, and among elderly people. The most plausible explanation of the opacity of the eye-lens is that it is due to coagulation of the lens protein, just as egg-white and other proteins may lose their transparency when acted on by certain chemicals or exposed to heat. To test the possible effect of radiation in this respect, excised pig and ox lenses were exposed to an electric furnace, being almost submerged in open vessels containing egg-white, blood serum, aqueous and vitreous humor respectively. When the exposed lenses and media were placed in a tank of running water (with the mouth of vessel slightly above its surface), even an exposure of 100 hours failed to produce any opacity. In other cases in which the media were placed very close to the furnace opacity occurred, but the temperature of the lens had risen to 80 degrees, and the conclusion was drawn that this, and not the red or the infra-red radiation, had caused the coagulation. Exposures to the visible spectrum gave rise to similar results. The filament of a 2,000-candle-power gas-filled lamp was focused on the lenses, but exposures for as much as 100 hours gave rise to no opacity. On the other hand, opacity could be produced in a few minutes by focusing the image of the sun on the lenses; but in this case also the rise in temperature was sufficient to account for the coagulation. Similar experiments regarding the effect of ultra-violet light were made. A Cooper Hewitt (2,500 candle-power) quartz tube mercury lamp was used. At a distance of 5 centimeters below the tube coagulation of egg white and blood serum occurred after 20 minutes' exposure, but the lenses were unaffected even after 100 hours, the aqueous humor was still clear, and the vitreous humor only slightly clouded. This is interesting, since practically all other protein substances can be coagulated by ultra-violet light. Now the author, by the analysis of cataractous eyes obtained from India, has found a great increase over the normal in the percentage present of certain chemicals. For example, eyes from India contained appreciable amounts of silicates of potassium and calcium; and in other cases various salts of these metals and of magnesium have been found. The presence of these materials therefore seems to render the protein liable to coagulation. This was confirmed by the author, who repeated the exposure to ultra-violet light on lenses immersed in solutions of magnesium chloride, sodium silicate, and dextrose. Turbidity and even total opacity could be produced in these circumstances. The conclusion woud seem to be that certain conditions of health, which gave rise to abnormal quantities of such materials (those suffering from diabetes, for example, accumulate increased amounts of dextrose), also predispose the eyes to cataract. There are thus two distinct factors: (1) the presence of these substances which modify the lens-protein, and (2) continual exposure to rays of short wave-length, by which the modified protein may be precipitated. The effective region in the spectrum of the quartz lamp appears to be from 265 $\mu\mu$ to 302$\mu\mu$, the former being the point of greatest activity.

The British Board of Trade issues from time to time small handbooks dealing with the trades of the principal manufacturing centers, designed especially for the use of advisory committees for juvenile employment. Some of the subjects treated of in these books are brazing, blacksmithing in connection with coach building, metal spinning, the electrical trades, gun making, safe and lock making, and a number of other employments.

[1] Noguchi, H.: Snake Venoms, 1909, p. 264.

[2] Welker, W. H., and Marshall, J.: The Toxicity of Rattlesnake Serum and Bile, with a Note on the Effect of Bile on the Toxicity of Venom, *Jour. Pharmacol. and Exper. Therap.*, 1915, vi, 563.

[3] Fraser: *Brit. Med. Jour.*, 1897, ii, 125.

Synthetic Phenol and Picric Acid*

Methods of Producing Materials Now in Great Demand

By Dr. A. H. Ney

UNDER normal conditions the world's demand for carbolic acid or phenol is amply covered by the amounts produced by the coal tar industry and the by-products recovery of the coke oven. The recovery of carbolic acid, crude and pure, from the so-called "creosote oils," that is, from afterrun of the light fractions and the forerun of the heavy fractions of the coal-tar distillation and the alkaline washings of the naphthalene fraction, has been developed to a high degree of perfection and refinement in England, the true cradle of the organic chemical industry. Pure carbolic acid (or phenol) has found extensive applications in the arts since its discovery by Runge in 1834, who first isolated it from coal tar. The aniline color industry employs it as an important intermediate product; together with its homologues, the cresols, it is extensively used in recent times for the manufacture of synthetic resins, and it is the starting material for salicylic acid and picric acid.

Owing to the extraordinary demand for the latter product in war time, the supply of natural phenol is entirely insufficient; moreover, the price of carbolic acid has been subject to considerable market fluctuations, while during the last decade, until the outbreak of the war, the price of benzol has remained remarkably stable. For this reason the synthetic production of phenol from a material always available in practically unlimited quantities has gained considerable importance. Chemical research, of course, has in time produced several ways for the preparation of phenol, synthetically from other materials. All these methods, however, possess no industrial importance, and I refrain from recounting them. They may be found in the literature, the references being contained in Beilstein and other reference books.

Faraday in 1826 prepared naphthalene sulfonic acid by the action of sulfuric acid on the hydrocarbon naphthalene. The technical importance of this operation, called sulfonation, was not realized until half a century later, when Wichelhaus introduced the alkali-fusion of aromatic sulfonic acid in the industry, and since that time the stupendous development of the aniline dye industry has found one of its mainstays in the introduction of the hydroxy-group into aromatic hydrocarbons by sulfonation and subsequent alkali-fusion. Beta naphthol, one of the most important intermediate products of the coal tar color industry, has been produced during the last thirty years in enormous quantities by this method, which is prototype for the synthetic production of phenol. In Germany, synthetic phenol has been produced in insignificant quantities in the last decade of the last century, but when England, during the Boer rebellion, placed an embargo on phenol and a considerable shortage occurred on the Continent, the chemical works of F. Raschig in Ludwigshafen engaged in the manufacture of phenol on a large scale and has maintained this whenever the price fluctuation of natural phenol permitted. The chemical works of Hoffmann-La Roche in Basle also produced synthetic phenol for many years and have always been able to compete successfully with the natural product for pharmaceutical purposes.

In this country, previous to the outbreak of the great war, synthetic phenol was never produced, however, not because of our inability, but for economical reasons. Thomas A. Edison, who was the first seriously to feel the consequences of the complete shut-off of the phenol supply, as he uses large quantities in the manufacture of his phonographic disk records, which contain the artificial resin prepared from phenol, as binder and are "faced" with a varnish of the same material, deserves credit for fearless and energetic action in quickly engaging in the manufacture of phenol from benzol. Already early last fall his plant in Silver Lake, N. J., produced synthetic phenol sufficient for his immediate needs, which are considerable. This most creditable achievement is only marred by the fact that the old and well known process was claimed as his own invention, and the appearance of exaggerated and foolish stories in the newspapers was permitted and countenanced.

With the arrival of demand for high explosives from Europe the demand for phenol increased enormously, and gradually other concerns began to prepare for the manufacture of phenol, and all of the many new organizations which were formed on the basis of often fictitious contracts for picric acid for the belligerent governments were compelled to consider the manufacture of phenol. While normally the price of synthetic phenol is about 9 cents per pound, with benzol at about 60 cents per gallon the cost price of synthetic phenol is about 18 cents. But when we consider that the price of picric acid is at present \$1.50 to \$1.75 for large contracts and that from one pound of phenol about 1¾ pounds of picric acid are obtained, we can see what enormous profits are theoretically involved.

THE MANUFACTURE OF SYNTHETIC PHENOL FROM BENZOL.

The synthetic production of phenol from benzol comprises the following steps and operations:

1. Sulfonation of the benzol by strong sulfuric acid.
2. The conversion of the resulting mixture of sulfuric acid and benzol-sulfonic acid into the calcium salts by adding milk of lime to the diluted sulfonation mixture.
3. Separation of the soluble calcium salt of the benzol-sulfonic acid from the gypsum by filtration.
4. Conversion of the calcium salt of the benzol-sulfonic acid into the sodium salt (and separation of the solution of the latter from the precipitated calcium carbonate).
5. Evaporation (to dryness) of the sodium salt of the benzol-sulfonic acid.
6. Caustic fusion of the sodium salt of the benzol-sulfonic acid.
7. Dissolving the fusion and acidulating the same to liberate the phenol formed and separating the same from the aqueous solution of the salts.
8. Distillation of the crude phenol.

(1) SULFONATION OF THE BENZOL.

This operation is carried out in the customary sulfonation kettles, consisting of a cast iron kettle of perhaps 300-350 gal. capacity, having a jacket of any preferred material capable of being heated, either by water, steam or an oil circulating system, to about 80 deg. C. The kettle is in this case preferably provided with bottom discharge. The lid must close tightly, a soft lead gasket having been found satisfactory. The lid is provided with man or hand-hole, thermometer pipe, 4-in. opening for running in the charge, an emergency opening, if desired, and connection to a spiral reflux condenser, water cooled, for condensing the benzol vapors. The kettles are elevated to permit gravity discharge into the liming tanks.

The stirring device is of the greatest importance. Owing to the great difference of the specific gravities of sulfuric acid and benzol, the tendency to separate into two layers and rotate as such is very pronounced, and it is obvious that in that case chemical action is very much impeded. The ordinary horseshoe type of agitator is therefore entirely unsuitable. Two types of agitators have been tried out, and both give about equal satisfaction. One type consists of a pair of ordinary propellers mounted on the shaft, one pair, however, being set conversely to the other; proper speed being 120-180 r.p.m. The other type consists of one complete turn of a broad spiral round the shaft, the whole revolving in a cylindrical case, which is either mounted on the shaft, rotating with same, or is stationary, viz., suspended from the lid or otherwise, a screw conveyor in fact.

For the production of one ton of phenol per day a battery of two kettles is necessary, each kettle being charged and operated twice.

In the cold or slightly warm kettle 410 lb. of sulfuric acid 98 per cent is run in, preferably from a measuring vessel common to all units of the battery. The agitator remains standing. One hundred and fifty-three pounds of benzol are next run in the kettle, the agitator still standing. The operator now closes all openings, excepting that leading to the reflux condenser, and starts the agitator. The temperature soon rises to 62-68 deg. or even higher.

When the thermometer indicates no further rise, heat is admitted to the jacket, and from now until the end of the operation the temperature is maintained as closely as possible to the boiling point of benzol; care, however, must be taken to prevent too energetic ebullition of the benzol, which would otherwise be thrown through the condenser.

The sulfonation requires from 5 to 9 hours (in the mean, 7 hours) and is finished when the odor of benzol is practically gone (it never disappears completely) and a sample of the sulfonation, when diluted with many times its volume of water does not separate any drops of benzol. No benzol di-sulfonic acid is formed under these conditions, and the amount of sulfon is negligible. With benzol of good quality and at least partially freed from thiophene, the color of the sulfonation mixture is light straw yellow; on cooling, benzol-sulfonic acid separates in fair quantities, occasionally in crystalline form.

(2) CONVERSION INTO CALCIUM SALT.

After completed sulfonation, the resulting mixture of sulfonic acid and sulfuric acid is run into about an equal volume of water contained in the liming tank. The liming tank may or may not contain a certain amount of milk of lime or calcium carbonate paste (from the soda tanks).

The liming tanks (two being necessary for the quantities assumed above, but will suffice for a much larger production) are wooden tanks, preferably, but not absolutely necessarily, lead-lined, with powerful wooden agitators of the "gate" type, all iron parts protected and having a lead steam coil or an open steam pipe. The capacity of each is 1200 gal.; 4-in. bottom outlet, flanged and "flush" inside, proper draining being assured by a slight tilt. Bottom outlet connected to filter press pump (or Montejus if used, which is not advisable).

The milk of lime is prepared in a suitable vessel, for instance a sheet-iron cylindrical tank with iron stirrer and a perforated cagelike basket, removable, in which the lime is placed. Suitable capacity 500 to 600 gal. A straining device should be attached to the outlet.

Suitable proportions for the milk of lime: 1 lb. of burned lime for 0.6-0.75 gal. of water.

The operation of liming is carried out as follows: Milk of lime is run into the diluted sulfonation mixture, the latter being hot due to the hydration heat of the acid. Steam is turned into the coil when the milk of lime begins to run in. The milk of lime is added just short of the point of alkalinity, viz., until all sulfuric acid and the largest part of sulfonic acid is neutralized; then sufficient calcium carbonate (chalk or from the soda tanks) is added to neutralize completely. The content has now begun to boil and is maintained boiling for about 20 to 30 min. If it should become too thick, a little water may be added. (Very little water is necessary to thin the mass.) The steam is then turned off and cold water equal to about 1½ volumes of the original volume of the sulfonation mixture is run in.

All these precautions serve the purpose of obtaining the gypsum precipitate in a form permitting rapid filtration and complete washing out of the press cakes with the least volume of water.

(3) SEPARATION OF SOLUBLE CALCIUM SALT FROM GYPSUM.

Two filter presses are desirable, but one may do. The filter press with washing device made by Shriver & Co., Harrison, N. J., is probably the best, but when ordering, it should be insisted that two washing inlets, one at the bottom and one at the top of the plate, are provided (which is done without extra charge). Open discharge. The lower washing holes should be worked first. Filter presses are best raised on a platform high enough to permit a dumping cart to be driven under it, into which the gypsum cakes are dropped through a chute.

The contents of the liming tubs are pumped into the press at a temperature of about 60 deg. C. and the filtrate collected in the soda tubs. The cakes are washed, by means of the washing attachments, with hot water, the first washing being added to the filtrate while the last wash water may be turned back into the liming tub in place of pure water for diluting the sulfonation mixture. The amount of wash water necessary depends largely upon the state and form of the gypsum precipitate, that is, if the same has been properly prepared and treated, comparatively little washing will be required, while, on the other hand, if it has been allowed to become slimy, it is very difficult to completely remove the calcium benzol sulfonate from it. The economy of the process depends to a large extent on this factor. Generally speaking the volume of the solution should not be increased more than 50 per cent by the washing operation.

(4) CONVERSION OF CALCIUM SALT INTO SODIUM SALT.

The filtrate and wash waters are run by gravity from the troughs of the filter presses into a wooden tub. Two are advisable, of a capacity of 1500 gal. They need not have a stirring device, but preferably have a light one, or may be agitated by air or even by hand. They may have a closed steam coil of good size, in order to evaporate while filling and to boil, which is necessary in order to obtain the calcium carbonate in the proper crystalline form. Soda ash (dry) is added until all calcium is precipitated, which point is recognized when further addition fails to produce more precipitate and by the slight alkaline reaction. No excess of soda should be allowed.

The calcium carbonate is allowed to settle, and the supernatant clear liquid is fed to the evaporator. After the layer of calcium carbonate has increased, say after three or four conversions, it is washed once with water and then withdrawn and used for neutralizing the sulfonation mixture.

(5) EVAPORATION.

Evaporation of the sodium salt is obviously carried out most economically in a multiple-effect vacuum evaporator

* A lecture delivered before the National Exhibition of Chemical Industries in New York City on September 24th, 1915.

and the drying of the salt in a vacuum oven. However, the temporary nature of the proposition does not always warrant the large investment for installing this apparatus, and any means for evaporation and drying, such as tanks with steam coils for concentration and jacketed shallow pans for drying, may be employed.

The dry sodium salt represents a dazzling white finely crystalline mass, which, for the fusion, should be pulverized to a coarse powder, any means to that end being suitable.

The yield of the sodium salt should be practically theoretical, any losses being mechanical and most probably due to incomplete washing of the gypsum cakes.

(6) CAUSTIC FUSION OF THE SODIUM SALT.

The caustic fusion is carried out in open cast-iron round-bottom kettles, of about 300 gal. capacity, having an iron stirrer of the horseshoe type, which should as closely as possible approach the sides and bottom of the kettle.

Two fusion kettles are preferably set in brick arch construction or sheet steel protector to prevent direct contact with the flame.

Heating means, preferably: gravity oil burner, size ½ in.

The kettle is charged with 480 lb. of caustic soda and 30 to 50 lb. water added, which facilitates the melting of the soda. The temperature is raised to 270 deg. C., and then 600 lb. of dry pulverized sodium salt of the benzol sulfonic acid are shoveled in. The temperature should not be permitted to fall, but should, during the throwing in of the sodium salt, rise, so that when all of the latter is in, about 300 deg. C. has been reached. This can be readily done by increasing the flow of the oil of the burner and by regulating the speed with which the salt is added. When all has been added the temperature of the fusion is raised to about 315 deg., whereupon the heat is turned off. The temperature rises a little further but should never exceed 330 deg. However, observation of the temperature is not very essential, as with a little practice the progress, etc., of the fusion can readily be observed and followed by the appearance of the same. A description of these visual indications, however, would help but little, and experience and a few trials in the laboratory will quickly enable the supervising chemist to determine the correct conditions. In general the fusion is completed when all sodium salt has gone into solution, and the melt becomes thin. No separation in two layers takes place with the above proportions.

(7) DISSOLVING THE FUSION AND ACIDULATION WITH LIBERATION OF PHENOL.

When still hot and liquid, the melt is ladled in shallow iron pans or trays and broken up after having solidified and cooled. A crusher might suitably be employed. The workingmen must be provided with rubber gloves and goggles and should be advised to protect their clothing with pieces of sacking. Clogs or wooden shoes, such as worn by the Lancashire mill hands, are also recommended.

The broken-up fusion cakes are now dissolved in water, two parts of water to one part of fusion. The best apparatus for this operation is a sheet-iron cylindrical tank with conical bottom, similar to a benzol washer; it need not be lead-lined as, in contradistinction to the separation of tar-phenol from the alkaline solution by mineral acids, no danger of over-acidulation exists, as acid is only added until bisulphite has been formed. The tank may be open, but should be provided with a hood.

A perforated false bottom, preferably arranged so that it can be lowered and raised and entirely removed, should be provided in the tank, and agitation is probably best provided by air. A lead-pipe with perforated coil, a little above the conical end, serves for running in the acid, and the usual arrangement for withdrawing the liquid at the bottom and at different levels should be provided.

When the cakes are dissolved diluted sulfuric acid from a lead-lined storage vessel is run in until the beginning of copious evolution of sulfurous acid indicates the beginning of the decomposition of the bisulphite. Five thousand pounds of cakes require about 2500 lbs. of sulfuric acid 100 per cent in form of 40 deg. Bé. The contents of the tank are now allowed to stand, the aqueous solution containing sodium sulphate and sodium bisulphite is subsequently withdrawn at the bottom, and the phenol freed from sulfurous acid by vigorously blowing air through it for some time.

(8) DISTILLATION OF CRUDE PHENOL.

The resulting crude phenol is now distilled from a phenol still and gives, after removal of the forerun, pure crystalline phenol of the highest melting point.

The yield obtained should be one pound of phenol for one pound of benzol.

The synthetic phenol thus prepared possesses frequently a very disagreeable odor characteristic of organic sulfur compounds. Whether this odor is due to the presence of thiophene in the benzol or to compounds formed by the reducing action of the iron in the fusion kettle (or possibly sulfonation kettles) on the sulfuric acid or sulfites, the writer expresses no opinion. This odor, however, can be readily and completely removed by digesting the crude or distilled phenol with common wood charcoal or still better animal charcoal, or distilling it over the same.

Traces of diphenol (dioxy-diphenyl) appear in the after run.

As in all similar cases, when an old established method suddenly obtains greater importance than was the case before, inventors, real and otherwise, have become active. In the case of phenol no tangible result has been obtained. All methods suggested as "short-cuts" in the sulphonation and fusion phases of the process have proven futile. Of course, modifications of the different steps are always possible. So it is, for instance, possible to sulfonate benzol with fuming sulfuric acid of various anhydride contents, but it is then necessary to keep the temperature of the reacting mixture well below 50 deg. as otherwise considerable amounts of disulfonic acids are formed, increasing, of course, with the concentration of the anhydride.

Another "invention" often submitted by would-be "phenol experts" is the direct production of the sodium salt of the benzol sulfonic acid by treating the sulfonate with solutions of common salt. This "invention" is based on the practice followed by certain beta naphthol manufacturers, but is unrational because of mechanical difficulties occasioned by the necessity of filtering strongly acid solutions. Furthermore, the "salt" thus obtained contains large amounts of Glauber salt, which are a nuisance in the subsequent fusion and require the use of larger proportions of caustic soda. The suggestion centering in directly neutralizing the sulfation and digesting the mess with caustic is too ridiculous to be considered seriously, and only demonstrates the deplorable ignorance in such matters of those who advance it.

Chlorbenzol is a fairly readily accessible, cheap material, especially if use is made in its manufacture of the chlorine produced by the electrolytic alkali manufacture. The chlorine atom in aromatic compounds can be replaced more or less readily by the hydroxy-group by digesting the chlorinated compound with alkalies. When more substituents are contained in the kernel, especially negative ones, the chlorine atom can be replaced very readily, but chlorbenzol is very inert in regard to this reaction and very high temperature and dilute solutions of caustic soda are necessary to perform satisfactorily this conversion. For this reason, which necessitates the use of autoclaves for very high pressure and large volume, the industrial application of this elegant short method for preparing synthetic phenol is out of question.

THE MANUFACTURE OF PICRIC ACID.

Picric acid is the tri-nitro derivative of phenol, the product of an exhaustive nitration of phenol, many of its derivatives and to some extent of many organic substances.

It presents pale yellow crystalline leaflets of exceedingly acrid taste soluble to about 1 per cent in cold water, more readily in hot water, easily in ether, alcohol and the usual organic solvents. F. P. 122.5. Ignited it burns, without explosion; detonated by fulminates (Ag or Hg) or guncotton it explodes and is one of the *brisantest* explosives. The salts are very explosive and also a detonator for free picric acid. Specific gravity of fused picric acid is 1.64.

The technical production of picric acid is to-day carried out by two distinct processes:

1. The first and oldest method, which even to-day is employed almost exclusively, consists in nitrating the phenol sulfonic acid obtained by treating phenol with concentrated H_2SO_4 at about 100 to 110 deg. until the odor of phenol has disappeared and the reaction product is completely soluble in water, with an excess of nitric acid, preferably in the presence of an excess of sulfuric acid.

2. The second and more modern method employs as starting material chlorbenzol, which is dinitrated to dinitro-chlorbenzol; this product is separated from the spent nitrating mixture, the chlorine atom replaced by the hydroxyl by heating with caustic soda, and the resulting dinitro-phenol is nitrated.

The possibility of a third commercial method for the production of picric acid is suggested by an old publication by Hepp., *Ann.*, 215, 344 (1882), who claims to have obtained, with an excellent yield, picric acid by oxidizing trinitrobenzol in alkaline solution with potassium ferric cyanide, the possibility of the use of other mild oxidizing agents being implied.

In view of the difficulty in obtaining trinitrobenzol with anything like a satisfactory yield, the commercial feasibility of such procedure is open to grave doubt, although the writer has private information that a small plant is at the present time producing picric acid to some extent by a process purporting to be based upon this method, literature on trinitrobenzol, Kekule, *Ann.*, 137, 167; Salkowski, Rehs, *Ber.*, 7, 371; Hepp. *Ann.*, 165, 18.

The chemical and technical literature contains many suggestions and several descriptions for the manufacture of picric acid, all of them, however, being obsolete. Chemically, the preparation of picric acid is very simple and easy and, as a matter of fact, it would seem almost impossible for anyone placing phenol and nitric acid together, in some form and manner, not to obtain picric acid. Technically, however, the manufacture involves several difficult problems, mainly due to the fact that the handling of straight nitric acid is a difficult and dangerous operation precluding the use of materials for receptacles, etc., usually employed in the chemical industry and the somewhat exaggerated fear of contaminating by inorganic salts, detrimental to the stability of the product. The drying and pulverizing of the material is a very dangerous operation, which, however, is now seldom required in chemical factories, the ordnance works usually requiring delivery of the wet crystals with a moisture content of approximately 20 per cent.

The manufacture of picric acid is carried out as follows:

A large sulfonation kettle of the usual construction, preferably lead-lined, with steam jacket, bottom discharge and agitator, is charged with one part phenol and four parts sulfuric acid, 98 per cent. The mixture is heated under agitation until a sample appears completely sulfonate, that is, soluble in H_2O without turbidity and the complete disappearance of the phenol odor. The content of the sulfonation kettle is now divided into the nitrators which are receptacles, suspended in a space adapted to have hot or cold water circulated therein. To the content of each kettle an equal part of sulfuric acid is added, and after reducing the temperature to below 20 deg. the nitrating acid is run in. The nitrating acid is preferably the usual mixture of equal parts of HNO_3 (40 deg.) and H_2SO_4, but any other proportion is equally suitable. Instead of three molecules required by the theory, four molecules of HNO_3 are added, the temperature being kept below 40 deg., while the first 30 to 40 per cent nitric acid is run in and then gradually increased to 70 or 80 deg., hot water being circulated toward the end of the operation and one to two hours afterward. Proper ventilation must be provided. Air may be blown through the nitrators before removing their content in order to remove the nitrous gases formed.

The content is now removed into an acid-proof, nonmetallic receptacle and diluted with water, about equal volumes having been found to give the best results. After cooling, the picric acid, which separates usually in large crystals, is placed on filtering means, "nutches" or centrifuges, and washed. The formation of too large crystals and "caking" should be prevented. It is usually of sufficient purity for any requirements. To obtain it still purer it may be fused in a steam-jacketed enameled kettle, from which it is run, if desired, through a sieve of platinum or gold, into a wooden tank with water. It is then filtered again. The method suggested in the literature of dissolving in alkali and again precipitating is unrational and dangerous and has never been practised by manufacturers.

The material from which the nitrators are made may be cast-iron, if the strength of the acid is always kept above 82-85 per cent, otherwise earthenware or enamel receptacles are indispensable. After the nitration the mixture is diluted, and for all final operations, contact with metals, other than precious, must be avoided. Coatings of a pure asphaltum varnish have given satisfaction. Proper agitation devices and ready means for discharging the nitrators and filling the same open a wide field for the ingenuity of the construction engineer.

The largest manufacturers of picric acid in the world (Hauff in Fuerbach) use an interesting and highly efficient filtering device. It consists of a filtering box or "nutch," with vacuum below and above, and is adapted to be used as both filter and dryer. The crude picric acid is placed on the filtering surface (a porous stone plate) and suction is applied. After the bulk of the adhering waste acid has been removed, alcohol is sprayed on the material and received in a separate container, from which it is at once rectified and recovered. The filter box is then covered with a specially constructed lid and vacuum applied; the drying proceeds very rapidly and the resulting product is very pure, due to the fact that it has been washed with alcohol, which is an excellent solvent for the resinous products, always formed during high nitration.

Hand Grenades in War

HAND GRENADES are supposed to have been introduced during the seventeenth century, and were employed more or less during the next hundred years, though later falling into disuse. We find mention being made of their reappearance at Saragossa in 1808-9, at Antwerp in 1832 and at Sebastopol in 1854-56. Some use was made of grenades by the British in 1884-6 in the Sudan campaign, but they did not come into any prominence until the Russo-Japanese war, where their value was demonstrated. The present conflict has seen the real revival of the grenade, largely because all parties to it are seeking every possible means of causing injury, no matter how crude, otherwise it would not be expected to find the ancient catapult and sling side by side with modern guns.

Potassium Photo-Electric Cells—I*

A Study of the Relationship of Illumination and Current

By Herbert E. Ives

The photo-electric current is a function of voltage, of electrode distance, of the kind of gas between electrodes, of pressure, and of illumination.

The *voltage-current* relation and the *electrode-distance-current* relation, under constant illumination, were the subject of study by Stoletow[1] and others some twenty years ago.

The effects of pressure variations and of different gases, again under constant illumination, were studied by Stoletow, Varley, and other investigators. All of these studies revealed a complicated relationship between the current and the variables in question, for which qualitative explanations have been offered in terms of saturation, ionization by collision, etc.

One of the most important relationships to be determined, both from its theoretical bearing and from its practical application, is that between photo-electric current and intensity of illumination.

Elster and Geitel[2] concluded from some early experiments that the current is directly proportional to the illumination. Lenard[3] reached the same conclusion. In

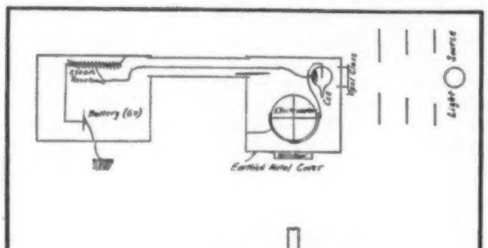


Fig. 1.—Arrangement of apparatus for "rate of drift" and "ballistic" methods of reading photo-electric current.

his results, however, the fact on which greatest emphasis is laid is that the final voltage acquired by the sensitive surface is a constant, independent of the intensity of illumination, while the current or rate of acquisition of voltage is certainly not a constant. Actually his figures show a current increasing more rapidly than the illumination. Lenard, accepting the linear illumination-current relationship as proved, has recently used alkali metal cells for measuring the decay of light in phosphorescence.

Griffith,[4] working with a zinc plate, illuminated by a spark, made careful corrections for air absorption and measured the current by a balancing method in which the electrometer served merely as a detector His results plotted take the form of a curve concave toward the current axis (similar to Lenard's values).

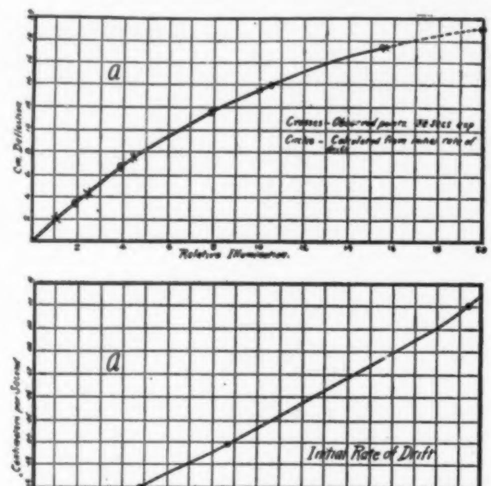
Richtmyer,[5] using a sodium cell, found a strictly linear relation between illumination and current, over an enormous range. He suggested various laboratory applications of the cell for photometric work.

Elster and Geitel,[6] in a paper appearing after a large part of the work here described was completed, found the photo-electric current, in cells having a gas atmosphere of a fraction of a millimeter, directly proportional to the illumination over an even greater range than Richtmyer investigated. They have developed a special form of cell having a surface of colloidal metal or hydride, with an atmosphere of inert gas at a pressure determined by them as giving great sensibility.

OBJECT OF PRESENT STUDY.

It appeared proved from the work of Elster and Geitel and of Richtmyer (which appeared subsequently to that of Griffith), that the photo-electric current is truly proportional to intensity of illumination. The extreme sensibility of the alkali metals is well established. Elster and Geitel, and later Pohl and Pringsheim[7] have shown the sensitiveness of the metals sodium, potassium, rubidium, and cæsium to extend well down into and through the visible spectrum, the maximum (of the "selective" effect) lying at progressively greater wave-lengths in the order in which the metals are above given.

It appeared to the writer to be desirable at this time to study thoroughly the alkali metal cell as a possible substitute for the eye in photometry, particularly in colored-light photometry. If it should be possible to



Figs. 2 and 3.—Illumination-current relationships obtained from cell *a* with preliminary apparatus.

produce cells of uniform wave-length sensibility, to develop a colored absorbing screen which should make the resultant spectral-sensibility curve that of an average eye,[8] then it should be possible to tie down to a purely physical instrument the characteristics of that wonderful, but most troublesome, physiological one—the human eye. The work was therefore undertaken as the logical continuance of the writer's study of heterochromatic photometry.

In order for a physical photometer to be available for anything except as a detector in a null method with lights of the same color, or for the measurement of lights of the same color where the intensity-response relationship has been determined, the relationship between the

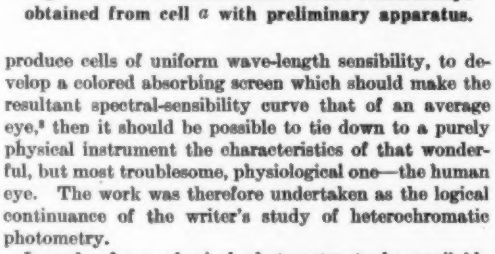


Fig. 4a.—Diagrammatic section of final arrangement of apparatus.

intensity of illumination and the resultant current or reaction must be a simple one, the same for all colors. The most desirable realtionship, as well as the simplest, is the linear one, which has been credited to the photo-electric cell. Granted that this simple relationship exists, the investigation as planned was to have been chiefly directed to the questions of the method of construction, performance, and reproducibility of the cells, their behavior under various photometric tests, the choice of alkali metal, and the specification of the proper color screen.

As will appear, the work took a different direction. The mode of construction of the cells and the methods of using them as heretofore described were not found satisfactory. Finally, when the first difficulties were overcome, the illumination-current relation was not found to be linear in photo-electric cells as heretofore constructed.

PRELIMINARY APPARATUS AND RESULTS.

Five methods of measuring photo-electric current are to be found in the literature: (1) by the rate of drift of an electrometer needle; (2) by the ballistic method, or the charge required in a definite exposure time by an electrometer connected to the cell; (3) by measuring the potential across the terminals of a high resistance in series with the cell; (4) by balancing the photo-electric current with a current variable in a known manner, using either an electrometer or sensitive galvanometer as a detector; (5) by the deflection of a sensitive galvanometer.

As a large part of the problem was anticipated to be the study of the wave-length sensibility-curves, the comparatively insensitive galvanometer method was not con-

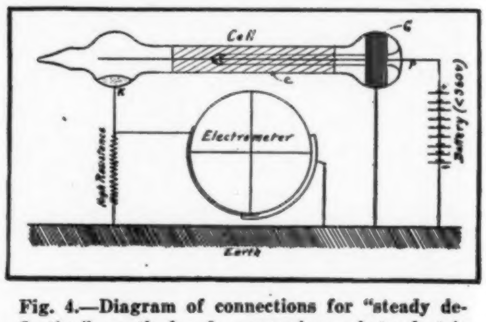


Fig. 4.—Diagram of connections for "steady deflection" method of measuring photo-electric current.

sidered. A Dolazalek electrometer (made by the Cambridge Scientific Instrument Company) was accordingly employed throughout the work. In order, in starting, to have the benefit of all previous work, a cell was purchased on the market. The metal was potassium, the cell had a quartz window (which was not necessary in this work), and was made by Müller-Uri. It is shown in the diagram, Fig. 6*a*.

The arrangement of cell, electrometer, and light-source was copied closely from that described by Richtmyer,[9] and is shown in Fig. 1. The cell and electrometer were placed on a metal shelf on a brick pier in the laboratory basement; a galvanized-iron cover fitted over them, pierced with openings for a set of keys[10] for connecting and disconnecting cell, electrometer, and known electromotive force for calibration purposes. Glass windows permitted the exciting light and that illuminating the electrometer mirror to enter. In a separate iron box, connected to the first by metal tubes, was a six-volt storage cell, discharging through a 2,500-ohm resistance, from which various voltages might be taken by a sliding contact. This latter was connected to the potassium and served to neutralize the contact electromotive force which in the dark causes a strong current. More will be said about this later.

The needle was charged to a potential of 100 volts by contact with a set of dry batteries. The needle was suspended by a quartz fiber of 9µ diameter (maker's figure), having a period of swing of about 18 seconds, and a sensibility when charged as above of about 33 centimeters per volt, as read by a telescope placed with the scale at 1.80 meters distance.

A standard carbon incandescent lamp of 10 candle-power, mounted on a long track, served as the light-source. Its light fell upon a piece of flashed opal glass covering the opening to the cell.

With the apparatus so arranged, following the procedure as outlined by Richtmyer, the first experiments made were on the response to various illuminations.

The rate-of-drift method was first used. Contrary to the findings of others, the needle did not "move at a uniform rate," but continuously and rapidly decreased in speed. All tests of insulation and other ordinarily

*From the *Astro Physical Journal.*

[1] *Journal de physique*, II, 9, 468, 1890.

[2] *Annalen der Physik*, 48, 625, 1893.

[3] *Ibid.*, 8, 149, 1902.

[4] *Physikalische Zeitschrift*, 14, 741, 1913.

[5] *Philosophical Magazine*, 14, 297, 1907.

[6] *Physical Review*, 29, 71, 404, 1909.

[7] *Berichte der Deutscher Phys. Ges.*, 12, 215, 349, 1910, and subsequent papers.

[8] Ives, "Photometry of Lights of Different Colors," *Phil. Mag.*, 24, 149, 352, 744, 846, 854, 1912.

[9] *Loc. cit.*

[10] See McClung, *Conduction of Electricity through Gases and Radioactivity.*

suspected causes of trouble were negative. Suspecting that a critical condition might exist, caused by the period of the needle having an unusual relationship to the rate of drift, attention was next turned to the second method of measurement above—the ballistic one. In this the cell is exposed for a fixed convenient length of time, the needle allowed to come to rest, and the deflection read.

Again an unexpected result was obtained, namely, that with each different exposure-time a different illumination-current relationship was found. For short exposure the plotted curve was convex toward the illumination axis. For long exposure it was concave. Fig. 2 shows the curve obtained for 30 seconds exposure. Fig. 3 shows the curve obtained for zero exposure—in other words, the initial rate of drift, as extrapolated from the rate of drifting over successive centimeter divisions on the scale. This latter, convex to the illumination axis, is of the character obtained by Griffith.

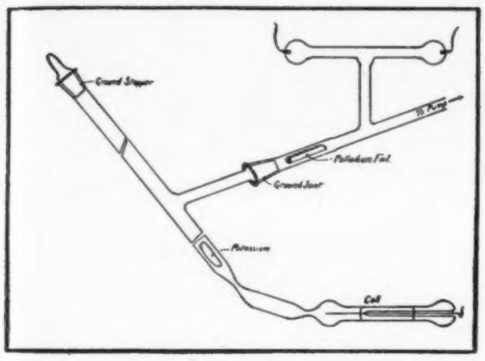


Fig. 5.—Arrangement for filling and exhausting cells.

By proper choice, then, of time of exposure, it appeared possible to obtain any curve desired, among others a straight line. But this apparent dependence on time of exposure called for explanation. It was consequently decided to make a trial of the third or steady deflection method, in which the effect of both needle period and choice of exposure-time are eliminated. This led to the construction of the apparatus as finally used, which will now be described, not as chronologically developed, but under appropriate headings.

FINAL FORM OF APPARATUS.

The electrometer.—After much trouble with defective insulation in damp weather and difficulty in making adjustments, each necessitating the removal of the sheet-iron cover, it was decided to inclose the electrometer completely in a dry, air-tight box, and arrange to operate its adjusting screws from without. Fig. 4 shows diagrammatically the arrangement for the steady deflection method, while Fig. 4*a* shows in section the electrometer and its accessories as practically arranged. The lower portion of the inclosing box is of heavily shellacked wood, lined with tin foil. Around the top is a narrow trough containing mercury. Into this trough sets the sheet-iron top, which in turn has an opening through which the needle support of the electrometer projects into a cut-off glass bottle, also seated in a mercury trough. By this latter means the electrometer mirror may be turned to bring any part of the scale into view. The leveling screws each rest on a small brass pillar, which moves as a piston in a sleeve mounted in the supporting shelf, stopcock grease making the piston air-tight. Each piston is moved up and down by a tapering rod, which is threaded into a fixed nut. Long handles carry this adjustment over to the observation table, two meters away. Adjustment is made by charging and discharging the needle with all quadrants earthed and altering the level until no change of needle zero occurs. When adjustment is apparently complete, it may be found that the needle does not hang symmetrically with respect to the quadrants. It is then raised or lowered slightly until on adjustment it is symmetrical. The raising or lowering need only be done on first setting up. Slight changes in level are found necessary from time to time, as shown by the disturbance of the zero on charging. The adjustment of the electrometer is a delicate matter and without some means of working from the position of observation is almost prohibitively tedious. When adjustment was completed, the deflections were found strictly proportional to voltage over the whole range of the scale.

The needle was charged with the aid of a small ionization chamber containing a small sample of polonium, as described by Erikson.[11] The arrangement of cell, screen, etc., is sufficiently well shown in the diagram. A single key, working through a glass-ground joint, served to earth the electrometer quadrants attached to the cell. Three mercury cups, on sealing-wax stands, were connected respectively with the source of high potential, the electrometer, and the earthed walls of the box. A metal tube, leading down from the box, carried the wires to needle and cell from the high-voltage batteries. Wires soldered to the electrometer shelf, cover, and tubes, and to gas pipes, insured complete earth connection.

Two trays of calcium chloride rested on top of the wooden part of the box and, in addition, a small tray of phosphorous pentoxide assisted in keeping the inclosure dry. During the later and more important part of the work the basement was steam-heated, whereby everything was made thoroughly dry, even without the drying material. After the cell and electrometer are closed up, they need not be touched for days or weeks, the best possible conditions being thus insured.

Source of high potential.—A battery of small dry cells provided the high voltage necessary to work satisfactorily with the steady-deflection method. These were cells of the kind used in electric flash-lamps, coming in cartons of five each. To insure perfect contact they were taken out of their cases and connected by soldered wires. They were then arranged in rows in four shellacked wooden trays, sixty to the tray. A switchboard on top of the tray-holder was arranged so that one, two, three, or four groups could be put in series, giving, when fresh, 90, 180, 270, or 360 volts. By direct wire connection from the cells intermediate voltages were available when desired. Each tray was connected by fine fuse wires, and a fixed resistance of 2,000 ohms was kept in series with the photo-electric cells for their protection. A key, worked by a cord over a pulley, effected the charging and discharging of the electrometer needle from 65 of the dry cells (100 volts). The entire battery system was inclosed in a galvanized-iron box.

High resistance.—Much time was spent in the search for a satisfactory high resistance. Alcohol in a capillary tube,[12] xylol and alcohol,[13] mannite solution with non-polarizable electrodes,[14] various forms of carbon resistances,[15] besides selenium, Welsbach mantle oxides, etc., were investigated. Alcohol and xylol-alcohol were found to become polarized and were, therefore, abandoned. Mannite solution in a long thermometer capillary proved free from polarization, but had to be made of very low concentration to secure high enough resistance in the length of the tube which it was feasible to use (perhaps owing to the conductivity of the water used as solvent). Its chief defect, however, was the difficulty of preventing evaporation and leakage in spite of the plentiful use of paraffin over all cocks and joints. The most satisfactory resistance was a modification of a carbon one described by Stewart.[16] A piece of dull-surfaced hard rubber had two machine screws tapped into it. Each machine screw carried a nut which could be screwed tightly down against the rubber. Lamp black was mixed in a commercial lacquer and painted around the electrodes, forming an adherent conducting coat. The two spots of lamp black were then joined by a fine lead-pencil line. In this way the chief difficulty with carbon resistance—erratic contact—was overcome. The resistance used in obtaining the curves here shown had a value of 150 megohms. With the electrometer sensibility used, one centimeter deflection thus corresponded to 0.2×10^{-9} amperes.

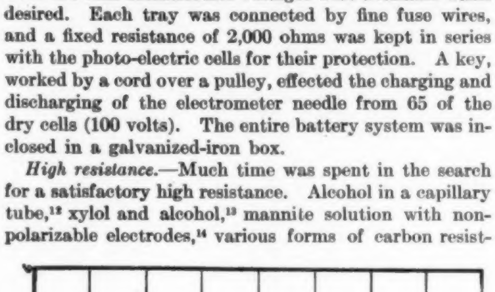


Fig. 7.—This shows the values of the deflections obtained from constant intensity × time. The deflections are not constant, which would lead to the suspicion that the photo-electric current is not proportioned to the intensity.

Source of light.—Electric incandescent lamps were used uniformly, of various candle-powers, their light usually falling upon a piece of flashed opal glass 5 centimeters from the cell surface. Occasionally, when an insensitive cell was experimented with, the opal glass was removed, allowing the light to fall directly on the sensitive surface. The highest illumination used was about 500 meter-candles on the opal glass, and the glass had an effective absorption of at least 90 per cent as used.

The electric lamps were controlled from storage batteries in the usual way and were mounted upon regular photometer carriages and tracks carrying screens to exclude all stray light. Exposure of the cell to the light was made by a shutter moved from the observing table.

CONSTRUCTION AND MANNER OF CONNECTING THE PHOTO-ELECTRIC CELLS.

The cell first used was, as above stated, a purchased one, and is shown in section in Fig. 6*a*. In order to make clear why this cell was not entirely satisfactory and why radical changes in construction were introduced, the manner of connecting up the apparatus will now be given. Fig. 4 shows diagrammatically the essential parts. The alkali metal electrode *K* is connected to one pair of quadrants of the electrometer and to earth through the high resistance. The other electrode *P* is connected to the positive terminal of the batteries.

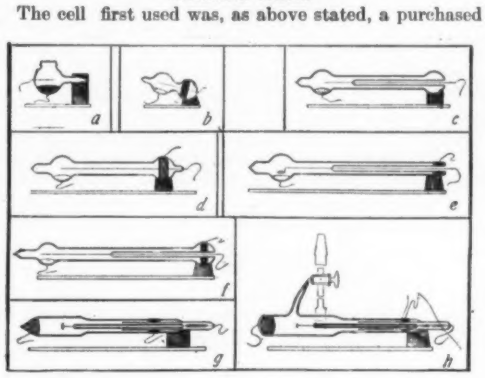


Fig. 6.—Types of cells used in the investigation.

Insulating and guard rings.—Two spurious currents, present in the dark, are found in the photo-electric cell as heretofore constructed. The first of these is opposite in direction to the current produced by light, and is ascribable to the contact difference of potential between the potassium and the other (platinum) electrode *P*. The second is what has been called a "dark current," in the same direction as the light current. These two currents may be so large as to be very troublesome, especially as they are likely to be variable in amount. No satisfactory result can be secured unless they are reduced to negligible values.

A series of experiments was carried out to learn the cause and method of obviating these currents. A recent paper by Elster and Geitel, appearing since the final form of cell here adopted was under trial, contains all the essential points about these effects, so that it suffices here to say that the "dark current" is the result of conduction over the surface of the glass, due either to the glass itself, to occluded water vapor, or to a thin film of carbon, deposited from the hydrocarbon with which the alkali metal is usually covered before use. It, in common with the contact electromotive force current, can be greatly reduced by using glass of good insulating quality, or by separating the two electrodes as far as practicable. A still more complete protection is afforded by the use of internal and external guard rings put on by chemical silvering and connected to earth. The cell shown in Fig. 4 represents the best form. At *G* are the internal and external guard rings, *C* represents an insert of cobalt glass tubing, which has a very high resistance compared with the ordinary clear soda-lime glass. The whole cell is mounted on a glass plate by a sealing-wax support at *G*, as shown in the sketches of Fig. 6. The insulating and guarding of the electrometer from *P* and from earth connection other than *R* and *G* is, therefore, excellent, as was shown by the fact that a cell similar to *C*, but made of ordinary clear white glass, gave with a certain high resistance and voltage a current due to contact electromotive force represented by 7 centimeters deflection, whereas with the cobalt glass inserted, as in *C*, this was reduced to less than a millimeter. The guard ring and cobalt glass together entirely eliminate the "dark current."

Details of filling.—The process of making and filling the cells was not found to be entirely easy, despite the published descriptions of the process. The pouring of liquid potassium through constricted tubing is very different from pouring mercury, although the two liquid metals look so much alike. Potassium has a very great surface tension, combined with a pronounced tendency to stick to the glass. As a consequence it is likely to pile up in front of a constriction or, on going through, to leave a thread of metal which can be removed only by heating to the distillation point, a process dangerous to the glass. Another difficulty is that of maintaining the surface clean, for, in spite of the most elaborate cleaning, first with hot chromic acid and later with nitric acid, caustic potash, and distilled water as a preliminary to the silvering operation, the glass surface

[11] *Physical Review*, 36, 253, 1913.

[12] Nichols and Merritt, *Physical Review*, 34, 475, 1912.

[13] Campbell, *Philosophical Magazine*, 22, 301, 1911; 24, 668, 1912.

[14] Pohl and Pringsheim, *Berichte d. Deutsch. Phys. Ges.*, 6, 174, 1913.

[15] Aust, *Physical Review*, 32, 256, among others, 1911.

[16] *Physical Review*, 26, 302, 1908.

gives up impurities which collect and float on the molten metal. As a result of a great deal of experiment it was found that a large body of potassium could be obtained clean if it was practically shot to place through the filtering constrictions and then allowed to cool at once. Any flowing about caused the collection of a film of scum. In Fig. 5 is shown the essential part of the apparatus for filling cells. The long tube has at one end a ground stopper through which is introduced a piece of potassium which has been scraped clean under benzol or has previously been distilled into a short glass tube. The Gaede mercury pump is then operated, the cell being inclosed in an electric oven raised to 200 degs. Cent. Exhaustion is continued for about an hour to allow all the gases to escape from the cell. Then a small flame is played under the metal and glass tube. The potassium presently melts, breaks through its coating of oxide, and, because of the steep slope of the tube, rushes through the two constrictions and into *C*. If necessary, the residue in the lower constriction is driven away by heating. After cooling, and then renewed pumping, the cell is sealed off. When desired, a small amount of hydrogen is introduced by heating palladium foil in the side tube. Pressures are read by a Gaede short McLeod gauge.

Far easier and more satisfactory is the method of filling by distillation. In this case the unfilled cell is silvered on the lower half of the bulb containing the electrode. The filling tube is inclined at a much less steep angle. A much smaller piece of potassium is needed. A flame is played carefully on the potassium until it vaporizes and the condensing film is driven over and down on to the silver. In order to obtain deposits of uniform character, the expedient was adopted of seating the bulb in a cup of mercury cooled by a jacket of carbon dioxide snow. By slow distillation a perfectly matt fine-grained layer is obtained. If done very slowly on to a highly chilled surface, colored colloidal films may be made.

Description of various cells used.—By the time the serious work on the illumination-current relation was begun, quite a stock of experimental cells was on hand, representing various stages of design. A number of the later ones were pressed into service, and as their individual characteristics probably affect the results obtained with them, a brief description is here given of all the cells. Pressures, where mentioned, are those of the pump system when the cell was sealed off. The gases given off by the molten constriction probably made the actual pressures greater. The cells are shown diagrammatically in Fig. 6.

a. Cell purchased from Müller-Uri. Solid mass of potassium; electrode distance 10 millimeters; originally possessed no guard rings, but later given an external ring of silvering to be connected to earth; pressure unknown.

b. Short double bulb cell, furnished with inside and outside guard rings; potassium distilled on silver; shortest distance electrode to potassium 10 millimeters. sealing-off pressure about 0.03 millimeter.

c. Cell with cobalt glass insert, but no guard ring; potassium distilled; shortest electrode distance 12 millimeters; pressure not recorded.

d. Cobalt glass insert; guard rings; distilled metal; electrode distance 14 millimeters; pressure unrecorded.

e. Cobalt insert; guard rings; distilled metal; ring electrode close to metal, distance 8 millimeters; pressure 0.002 millimeter.

f. Cobalt glass insert; guard rings; distilled metal, transformed to hydride by glow discharge; electrode distance 15 millimeters; pressure 0.3 millimeter.

g. Cobalt glass insert; guard rings; solid metal; electrode distance made variable; pressure 0.005 millimeter.

h. Cobalt insert; guard rings; solid mass of potassium; electrode distance variable; side tube with stopcock for attachment to pump to permit variation of pressure.

Tubes *g* and *h* will be described fully hereafter.

Tubes *j* and *k* were kindly loaned to the writer by Dr. Saul Dushman, of the General Electric Company Research Laboratory, near the conclusion of the work. *J* is a cell purchased abroad recently; it has a colored hydride surface, is furnished with exterior tin foil guard rings, and is presumably one of the recent argon-filled type. *K* is a cell prepared by Dr. Dushman, similar in appearance to *a*, but several times larger and without the quartz window. It was exhausted to the best vacuum attainable with a Toepler pump.

It is unfortunate that students of the photo-electric effect have usually been interested either exclusively in determining currents or exclusively in determining the potential acquired by the sensitive surface. Had they been studying both, there would probably be fewer unqualified users of the rate of drift method of measuring current, working on the assumption that the electrometer needle moves at a uniform rate indefinitely.

The most important fact to keep in mind when using the electrometer to measure current is that the instrument forms part of the electrical system and as such may exert on the phenomenon under study an effect far from negligible. It is imperative that the possible disturbances due to the instrument be thoroughly understood before conclusions are drawn from its indications.

If the current obeys Ohm's law, the largest safe deflection is that corresponding to 1 per cent of the applied voltage.

If, now, the current, instead of obeying Ohm's law, is a saturated one, it is easy to see that the criterion for safety is that the applied voltage shall be sufficiently above the saturation voltage, so that the voltage difference between the electrometer and the source of high potential remains a saturation voltage for all voltages acquired by the electrometer. The difference possible between working with an ohmic current and a saturation current is illustrated in the hypothetical case where 100 volts are applied. If the current obeys Ohm's law one volt deflection is the permissible limit. If the saturation voltage is below 100, say 80, then the electrometer may charge up to 20 volts without the current being misread, i. e., the high-resistance leak may be of 20 times larger value and the sensibility consequently 20 times higher.

Where the current is not clearly of either the foregoing characteristic types, it is perhaps best to make an experimental determination of the effect of the high resistance. In the present work two resistances of relative strength about 1 to 5 were kept on hand, and in doubtful cases the ratio of large and small illumination-currents was taken with both resistances.

(To be concluded.)

Paint and Dye Testing*

Use of the White Flame Arc as a Standard

By Wm. Roy Mott

The white-flame arc at 25 amperes affords light at two feet (60 centimeters) distance more intense than summer sunlight; and unlike sunlight, this white light is exactly reproducible and available twenty-four hours in every day. Sunlight varies continually, due to shifting solar position and changing atmospheric conditions. Dyes and paints have been generally tested in sunlight because until the invention of the high amperage white-flame arc, sunlight was the most intense light practically available. Some good work has been done with the pure carbon arc and with the quartz mercury arc; but these are limited in value, the first by low intensity and the second by the source of the action being ultra-violet light, which is often different from the action of ordinary light. The high amperage white-flame arc has forced out all other forms of illumination as the cheapest, most powerful light source for photo-engraving. It is taking its legitimate place for blue-printing, for photographic studio work, and for laboratory and industrial manufacture of chemicals by light. The writer has made several hundred comparisons of the action of sunlight and of white-flame arc light on dyed fabrics and on paints and feels that sufficient has been done to invite a general consideration of this light in dye and paint investigations. There are great possibilities of new apparatus, of new fields and of a re-survey of the general field under definite, reproducible and efficient conditions.

GENERAL FACTORS.

The action of light on dyes may take the following courses: (1) Fading without other color change, (2) darkening before fading, (3) change to a different color tint, and (4) composite effect as to depth into cloth, so that on viewing underhand (overhead) the cloth is darkened and on viewing overhand (at an angle) the cloth appears faded. The fastness of dyes may run through extremes of fading in a few hours in sunlight to lasting several months. Graded steps of exposure are necessary to follow the resuts of which are often complex combinations. There are six major factors affecting the action of light. These are: (1) kind and intensity of light, (2) atmosphere, (3) dye, (4) fiber, (5) mode of applying dye, including mordants, fillers, etc., and in paints, nature of oil and varnish medium, (6) temperature.

(1) *Kind and Intensity of Light.*—The light has the least action when of the same color as the dye, due to the first law of conservation of energy, that the energy reflected cannot do chemical work. The complementary color (light absorbed), as pointed out by Bancroft and others, has the most action. In case of absorption of blue and other rays (red or green) there is generally more effect with the blue rays than with red or green. The effect of intensity of light is such in some cases as to entirely change the reaction. Even in simple cases the curve changes through three or four types of equations. The intermediate step generally obeys a logarithmic law for photographic paper. At very low intensities there seems to be a limiting point of reaction. Also, in some cases there is a storage of energy so as to obtain effects similar to latent images.

(2) *Atmosphere.*—By working in vacuum many fugitive dyes resist sunlight. There are a few rare exceptions. Gebhard says that under every-day conditions oxidation is the chief factor. The protective action of varnishes is, according to Toch, to prevent oxidation. Moisture in the air is favorable to the immediate action of light. Vapors of ammonia or alcohol greatly increase the action of light. Highly diluted acids, as found near towns, act protectively.

(3) *Dyes.*—The constitution of the dyes has been studied in relation to fading by Gebhard and many others. Many of the coal-tar dyes are reported as fast as the best mineral pigments.

(4) *Fiber.*—Many dyes have similar effects on silks and wools. With cottons, there are greater differences. On paper, it is very difficult to get a fast dye.

(5) *Mode of Applying Dye, Including Mordants, Fillers, etc.*, and, in paints, nature of oil and varnish medium. The references cover details too complex to give here.

(6) *Temperature.*—In general, the temperature coefficients of light reactions are small. I have, however, discovered exceptional results with lithophone, but even here the results are probably due to the superposition of secondary chemical actions.

TESTING IN SUNLIGHT.

Tests have shown that the chemical action of sunlight often varies to double in power, although the sky may be clear. The sunlight varies because of variations in solar emission, shifting position of sun, and changing atmospheric conditions. Noon sunlight is usually several times stronger in action than four hours sooner or later. In the winter time the actinic values are several times lower than in the summer, and the day is only about half as long. Daylight means an expensive arrangement for protecting against rain, wind, etc. "One observer may expose his patterns in the open to the joint action of sunlight, wind, rain, and possibly frost; another may expose under glass and place the patterns so as to get the largest possible proportion of the direct rays of the sun, or he may perhaps expose in diffused daylight only.

Again, the depth of the shade, the climate, the condition of the atmosphere, the time of the year, are all important factors which must necessarily be taken into account if anything like an accurate result is to be arrived at. With the possibility of such varying conditions, it will be easily understood how one observer may obtain a result which leads him to infer that a color is not fast, whereas another, who may have exposed the same color for the same length of time, concludes that the color is fast. It is to be regretted that we have no recognized standard for testing of color as to their fastness to light, and much credit would be due to anyone who would take the trouble to work this out. It would undoubtedly be a step in the right direction if, when exposing to direct sunlight under glass, we could agree as to which position the board, on which the patterns are fixed, should be placed in, and, in giving the result, mention the number of hours of direct sunlight (measured by the sun recorder) and of diffused light to which the patterns have been exposed. By a series of experiments, the ratio of destructive action of direct sunlight and the average of diffused daylight could possibly be determined, and we should thus be enabled to express the duration of exposure in one term, viz., hours of direct sunlight. If this were done, there would be much less divergency of opinion regarding the fastness of colors to light. For exact measure, however, it would be necessary to measure the

* Paper presented at the 28th general meeting of the American Electrochemical Society, in San Francisco, September 16-18, 1915.

average intensity of the sun's rays during the different seasons of the year and for different climates. (See Knecht, Rawson and Loewenthal, page 744.) The method of testing used by these gentlemen was to expose under glass, facing south, with part of the pattern covered with thick cardboard. If it has stood a month's exposure in summer without any material alteration, it may be called fast.

My sunlight tests were made in June, without glass, under direct sunlight in the hours 7:30 A. M. and 4:45 P. M. The patterns were placed horizontally. The patterns were taken indoors whenever the sun was obscured by clouds. Fifty hours of such direct sunlight required between two and three weeks. The exposure was on the roof of a building receiving light from nearly all the sky as well as from the sun. I find that the actinic power of the blue sky varies between 20 and 50 per cent of the total effect. By measuring the actinic effect of a ray of sunbeam let into a dark room, the light of the sky is largely eliminated. If the sky is overcast with clouds then the diffused light may become nearly 100 per cent of the total.

In the literature it will be found that considerable work has been done to measure the changing actinic effect of sunlight, but a complete solution has not been secured. Gebhard points out that sunlight is variable in color as well as amount. The devices proposed for measuring chemical action of sunlight are clumsy, but it must be admitted are better than no effort at standardization. Probably the standardized results afford a variation of 20 per cent. The unstandardized results are often such that the stronger effect may be twice the weaker.

THE 5,000 M. S. C. P. WHITE-FLAME ARC.

The high amperage white-flame arc has been in use only a few years, but practically all photo-engravers have adopted it because of its efficiency, power and quality of light, which is the best known for color-process work.

The outside spectrum is that of the white-flame arc, which is seen to have an enormous number of light-giving lines filling the spaces between the cyanogen bands and superposed upon them, resulting in a better light than the inclosed arc even at the same or greater efficiency. The spectrum of the white-flame arc is *equally* rich in the green, yellow and red regions. The extreme closeness of the lines gives a light nearly the same in continuity as sunlight, which has its dark lines (Fraunhofer lines). The candle-power of the high-amperage white-flame arc is exceptional in tremendous size of unit available and of greater efficiency than other forms of illumination. The following table contains average results as to mean spherical candle power and mean spherical photographic power. The average relative time to affect equally folio paper with the lights in a two-meter sphere is the basis of photographic power. We can all admit, as Mees says, that this is no scientific definition. A 28-ampere Aristo lamp was used with white-flame carbons under open arc conditions and without any globe. A comparison with the nitrogen-filled lamp is given:

TABLE I.

	Line Volts.	Arc Volts.	Amperes.	Mean Spherical.	
				Candle Power.	Photo Power.
White-flame arc (open)	115	63	28.0	5130	100
Nitrogen lamp—clear globe	117	117	6.7	866	4
Nitrogen lamp — blue globe	115	115	8.5	485	5

It is extremely conservative to say that for an equal amount of electrical energy the photographic power of the white-flame arc is six to ten times greater than that of the nitrogen-filled incandescent lamp.

GENERAL NOTES ON LAMPS AVAILABLE.

The above tests were made with the Aristo lamp on direct current. Tests with alternating current show greater value, due to the response of the flame arc to the voltage component of the power and to other factors. The photographic power of the flame arc increases nearly four times when the current is doubled and nearly proportional to the arc voltage. On a fluctuating line voltage it varies less than half as much as the nitrogen-filled incandescent lamp and is perfectly indifferent to all kinds of electrical and mechanical shocks. There is thus a greater service power for reproducing results. In most of these tests an Aristo lamp was used on 110 volts with the globe removed. An ordinary 5-ampere, inclosed-arc lamp can be arranged with a shunt to carry 20 amperes at 55 volts around the lamp resistance and solenoid, to operate at 55 amperes at the flame arc. A publication of this arrangement will be made in detail later.

There are a large number of standard lamps on the market that can be adopted. The Macbeth, Bogue and Helios are commercial lamps used in photo-engraving. In some of the fading tests, a 220-volt Macbeth flame arc at 25 amperes and 90 arc volts was used.

LIGHT OF DIFFERENT FLAME CARBONS.

The most valuable flame carbon for fading tests is the snow-white flame carbon. This has the maximum actinic power with or without the interposition of glass. Also it approaches very closely to sunlight with blue skylight. The flame carbons were used chiefly in 10 millimeters by 305 millimeters as lower positives with an ordinary ½ by 12-inch (1.3 by 30 centimeters) inclosed-arc cored upper carbon. In some cases ½ by 12-inch (1.3 by 30 centimeters) flame-cored carbons were used. The chief characteristics of these carbons are given in the following table:

TABLE II.

	Light.	Photo Power.
Snow-white flame carbon	Like sunlight plus blue skylight	100
Blue-flame carbon	Rich in ultra-violet	60
Yellow-flame carbon	Rich in red, yellow and green	35
Red-flame carbon	Rich in red	30
Pure carbon arc (10 millimeter shell)	Next to snow-white in quality	40

The photographic power represents the inverse of average time to attain equal shades with solio paper. The effect here is chiefly that of the short waves.

TEST ARRANGEMENTS.

The best arrangement so far has been with a set of 20-inch (20-centimeter) hoops around the Aristo lamp at 28 amperes. This provided a good circulation of air to keep the samples cool and for carrying the arc p oducts up. There were tested at the same time a couple of hundred small samples secured from standard dye houses. Only a small piece of sample was exposed and the rest covered with heavy blotting paper. Then the other end of these samples was exposed to sunlight for fifty actual hours of sunshine. Also tests were made in front of a 25-ampere, 220-volt Macbeth lamp with 90 arc volts. In this case, a flat board was used and no correction for the change in distance from the light was possible. No doubt, much better arrangements can be developed.

COMPARISON OF ACTION OF SUNLIGHT AND WHITE-FLAME ARC.

A sample book, entitled "The 1912 Fashionable Colors," was obtained from Farbwerke vorm. Meister, Lucius Bruning, Hoechst am Main. This gave the following results for the standard color on wool. (The goods are dyed 1½ hours at the boil in an acid bath with addition of 10 to 20 pounds Glauber's salt and 3 to 5 pounds sulphuric acid or with 7½ to 12½ pounds tartar substitute. The amounts refer to 100 pounds of material.)

Per Cent.	Dye.	Standard Colors. Exposed to 50 Hours June Sunlight.
2	Flavazine L	No change.
2	Flavazine S	No change.
2	Flavazine T	No change.
2	Victoria Scarlet 2R	No change.
3	Brilliant Crimson O	No change.
2	Sulpho Rosazeine B	Darkens with loss of brightness.
1½	Amido Naphthol Red BB	No change.
1½	Amido Naphthol Red 6B	No change.
3	Alizarine Direct Blue E_1BO	Darkens with loss of brightness.
1½	Patent Pure Blue O	Darkens with loss of birghtness.
2	Patent Blue V new	Darkens with loss of brightness.
3	Naphthalene Green V	Darkens with loss of brightness.
2	Acid Violet 6BN	Slight change.
3	Amido Blue GGR	No change.

Viewing at an angle, the fading is, of course, lighter. The five dyes showing most effect alone are equally conspicuous in the mixtures. As the dye is diluted with unlike color, the effect becomes sharper. The effects in sunlight for 50 hours were duplicated by the light of the white-flame in 10 to 20 hours. This was also true of the 132 mixtures. The fading action was far more marked with dilute solution. For example, 116 per cent Sulpho Rosazeine B was nearly bleached, although 2 per cent showed only a slight darkened effect viewed directly from above. The action of light on Sulpho Rosazeine B was marked in mixtures 25, 26, 27, 67, 68, 69, 73, 74, 75. These numbers refer to the 1912 book. The Patent Blue V new showed marked change in 10, 11, 12, 13, 14, 15, 127, 128, 129. The Patent Pure Blue O changed much in 67, 68, 69. The Alizarine Direct Blue showed marked changes in 4, 5, 6, 7, 8, 9, 13, 14, 15, 34, 35, 36, 49, 50, 51, 52, 53, 54. Dyes with Naphthalene Green V showed only slight changes. The most marked color change was with 127, 128 and 129. Here a bright blue changed to a reddish purple. No. 127 consisted of 0.6 per cent Sulpho Rosazeine B, 0.15 per cent Patent Blue V new, 0.02 per cent Alizarine Direct Blue. All these colors separately are affected by light and hence the unusual effect on the composite is not surprising.

The 1914 Color Book of the Farbwerke vorm. Meister, Lucius & Bruning, Hoechst am Main, shows a marked improvement in the fastness to light of the dyes of the 1912 book. None of the color mixtures faded nearly as much as those of 1912. In these tests 50 hours of sunlight was compared with 25 hours of the light of a 220-volt 25-ampere Macbeth white-flame arc at two feet distance. The flame arc light had the same kind of an effect as sunlight. With the blues and greens, there was fading as before, and no change occurred with 2 per cent yellows or reds. The troublesome Sulpho Rosazeine B (of 1912) was eliminated. A new brown (Amido Yellow E, pat.) had been added. This darkened a little.

The Amido Naphthol Red BB at 0.6 per cent showed a little fading. A mixture (No. 125) of 0.6 per cent Amido Yellow E, 0.06 per cent Alizarine Direct Cyanine 3 G and 0.009 per cent Patent Blue V new, showed a change from olive green to a decided brown. The Naphthol Green V and Patent Blue V new showed the most change under light.

Cassella Color CompanyCatalogue No. 3317, Dyestuffs for Wool, gave the following results, comparing 50 hours sunlight and 20 hours light of white-flame arc at 10 inches (25 centimeters), with good ventilation. The white-flame arc gave nearly the same effect as sunlight; for this reason a separate column is not given except for 100 hours with the flame arc, equivalent to about a year of ordinary light.

A series of ninety chromated dyes showed no change in 50 hours of sunlight or in the light of white-flame arc for 20 hours.

A series of sixty diamine dyes showed a few fadings of blue in sunlight. The tests in the flame arc light were not completed, but the action was in same direction as far as tested.

Some aniline colors from the Heller & Merz Company gave the following results:

On Wool.	50 Hours Sunlight.	10-20 hours Flame Arc, 10 inches (25 centimeters).
Patent Blue B	Darkened	Darkened
Acid Violet 4BNS	Darkened	Darkened
Acid Green 2CX	Darkened	Darkened
Naphthol Yellow L	Darkened	Darkened
Chrysophenine E. S. Conc.	Slight darkening	Slight darkening
Scarlet 4R Brilliant	No change	No change

These also resisted distilled water except the blue. The yellow and blue were most affected by light.

On Cotton.	50 Hours Sunlight.	10-20 hours Flame Arc, 10 inches (25 centimeters).
Pheno Blue 7B Conc.	Darkened	Darkened
Pheno Violet BK Conc.	Slightly darkened	Slightly darkened
Pheno Green KDX	Slight change	Slight change
Primuline Conc.	Much darkened	Much darkened
Chrysophenine E S Conc.	Slight change	Slight change
Pheno Orange R	Darkened	Darkened
Pheno Fast Scarlet 4B	Darkened	Darkened

All these cotton dyes, except the light yellow, gave colored solutions with distilled water. In six hours' direct sunlight the yellow had darkened to a brownish yellow. The action of the white-flame arc light was the same as sunlight. With cottons and the Macbeth 220-volt at two feet, some fading was obtained in two hours for Primuline conc., Pheno Violet 3K conc. and Chrysophenine E. S. conc.

Some cheap bunting (retailing at 5 cents a yard) was secured from a store in Cleveland. These were said by the merchant not to be fast to light.

Color.	50 Hours Sunlight.	8½ hours Macbeth Lamp, 2 feet (60 centimeters.)
Black	No change	No change
Violet	Greatly faded	Faded
Dark blue	Greatly faded	Slight fading
Baby Blue	Change to pure white	Bleached
Dark Green	Faded	No change
Light Green	Change to pure white	Nearly bleached
Yellow	Greatly faded	Nearly bleached
Red	Turned brown	No change
Purple	Greatly faded	Nearly bleached

The four most rapidly fading buntings were made the basis of several comparisons as to effect of increasing increments by one hour ot exposure, of effect of light from different flame carbons, of light from different flame lamps and of comparison of D. C. and A. C.

The blue-flame arc was very rich in ultra-violet light and had over twice the effect on the purple as on the baby blue or light green. It is unfortunate from the standpoint of dye fading that ultra-violet light often has very different proportional results on different dyes as compared witn sunlight. With only two hours' exposure, the other buntings except the yellow showed practically no change. The light green and purple were faded a little more with sunlight at 50 hours than the Aristo at 10 inches (25 centimeters) for 10 hours. The brightest June sunlight and skylight for 50 hours was more effective than 10 hours with Aristo at 10 inches (25 centimeters) and less effective than 20 hours. The Aristo at 10 inches (25 centimeters) was twice as powerful as the 220-volt Macbeth at two feet (60 centimeters).

Comparison with a nitrogen filled lamp on 110 volts D. C. at 6½ amperes, 1,000 watt unit with clear glass.

Table showing time for equal effect Aristo at 10 inches (25 centimeters) with nitrogen, lamp at 10 inches (25 centimeters) for one hundred hours:

	Time of Equal Effect Aristo.	Times Greater Speed with Flame Arc.
Baby Blue	3 hours.	33
Pink	1 hour.	100
Purple	3 hours	33
Light Green	6 hours.	17

The action of the incandescent light on the other bunting was as follows:

Black	No effect
Violet	Faded
Deep Blue	Faded
Green	Faded (more blue tone)
Yellow	Slightly faded
Red	No effect

The large excess of red and yellow rays and deficiency of blue rays has increased the action on the green (yellow absorbed) and decreased the action markedly on the red and yellow. The colors most easily faded by the incandescent lamp are the greens and least easily faded are the reds and yellows.

Some comparisons were made between the D. C. Aristo and A. C. Aristo with a material advantage for the A. C. in speed.

Tests on linens. A little over one hundred samples of colored linens were exposed on separate parts to 50 hours' sunlight and 10 hours' white-flame arc at 10 inches (25 centimeters). The 10 hours of the white-flame arc gave in all cases more effect than 60 hours of sunlight. This 50-hour period was not at the same time as the first set with the wools and cottons. The sky was somewhat murky and at times there were some small fleeting clouds during two of the days of the test. All the samples faded by sunlight were faded to a greater degree by the light of the white-flame arc. Excepting black, none of the samples of dyed linen could resist 10 hours with the white-flame arc.

ACTION OF PAINTS, WITH SPECIAL REFERENCE TO LITHOPHONE.

A number of sample books of paints were exposed to sunlight and to the light of the white-flame arc and the similarity of action was noted. Samples supposed to contain chrome yellow turned green, perhaps by a reducing action of organic matter on the chromate. In many cases the tints were brightened by the bleaching of the linseed oil, etc.

Some tests by Mr. B. Perris, of the National Carbon Company, showed considerable fading of the best enamel sign paints after one hundred hours' exposure to light of a 25 ampere, white-flame arc at two feet. This test is probably about equivalent to one year of ordinary sunshine in this latitude.

Lithophone ($ZnS.Ba.SO_4$) under the action of the light did not respond as rapidly as expected. Lithophone is well known to turn gray or even black on exposure to intense light, and later this dark color may turn to pure white in the absence of light or even in subdued light. Mr. O'Brien has published a very interesting article on the cause of the changes in color of lithophone. Two samples of lithophone were made up with a 1 per cent solution of gum arabic and painted on glass with a camel's hair brush. This was allowed to dry and then it was exposed with the paint side to the light. The response was slight and mostly at the protected edges directly two feet (60 centimeters) in front of the 220-volt Macbeth flame arc. I believe that the heat of the flame arc hastened the oxidation of the black zinc metal film as fast as formed and so I arranged the experiment with part of the plate cooled by being fastened by rubber bands on a large block (25 pounds, 11 kilogrammes) of ice. The part now kept cool by the ice blackened in a fraction of an hour and the part not cooled by the ice remained white after several hours. This experiment was conclusively repeated several times and proves the great importance of temperature as regards the blackening of lithophone under light. Under fifty hours of sunlight the lithophone darkened greatly. The interposition of glass greatly decreased the effect.

The following table shows that the maximum darkening of lithophone is given by the light of the blue-flame arc due to its large amount of ultra-violet light. The tests were made at two feet (60 centimeters) with 25 amperes arc at 90 arc volts on a 220-volt D. C. line. Samples ice cooled.

	Exposure of Half hour	on Standing in Dark.
White-flame	Blackened	White few hours
Blue-flame	Rapidly blackened	Black after week
Yellow-flame	Blackened	Black after week
Red-flame	Blackened	White one hour

The parts not ice cooled remained white in all cases.

The blue-flame arc gave the most effect. By exposing for five hours and keeping cool with ice, black coatings were obtained that were still black after one week. I have carefully read Mr. O'Brien's article and find no mention of this temperature effect, which appears to me to admirably support his theory of the cause of the blackening and subsequent whitening of lithophone. It also gives an added reason why lithophone is so well suited for interiors, with their higher temperatures.

CONCLUSIONS.

(1) For dye and paint testing as to fastness to light, there is found in the high amperage flame arc a light more powerful than sunlight, and, unlike sunlight, exactly reproducible.

(2) Different colored flame effects can be secured by using specially designed carbons which give colored lights as follows:

Snow-white flame carbons, nearly equal to sunlight plus blue sky.

Blue-flame carbons, strong ultra-violet light.

Yellow-flame carbons, rich in red, yellow and green but weak in blue. Some violet and ultra-violet.

Red-flame carbons, strong in red light.

Pure carbon arc, far inferior to the snow-white flame arc.

(3) Hundreds of dyes have been compared in best June sunshine and in the light of the snow-white flame arc, with essentially similar results, but at much greater speed.

(4) The best June sunlight for 50 hours gave an effect equal to between 10 to 20 hours of 28 ampere white-flame at 10 inches (25 centimeters). A more definite statement is impossible owing to the large variations of sunlight on even clear days.

(5) The 1,000-watt nitrogen-filled incandescent lamp required 100 to 17 times greater exposure for equal effect at like distance than a 28-ampere flame arc with 55 volts at the arc. A deficiency in the blue in the light of the incandescent lamp caused considerably different results from sunlight.

(6) The blue-flame arc was rich in ultra-violet light and therefore caused, with different dyes, results not proportional to sunlight.

(7) With the white-flame arc tests could be made in 10 hours, requiring otherwise about two weeks with sunlight under the change of weather common in the northeastern part of the United States.

(8) Some cheap buntings (pink, baby blue, pale green) showed fading in one hour with the light of the white-flame arc.

(9) Fading was most marked with diluted dyes. Same also shows in complex mixes.

(10) The 1914 colors showed marked improvements over the 1912 colors as regards fastness to light.

(11) Lithophone gave the maximum darkening (also of greatest persistency) by exposure to the light of the blue-flame carbons rich in ultra-violet light.

(12) Experiments on lithophone showed maximum action at low temperatures. This result supports the theories of O'Brien and Bancroft on the cause of the darkening of lithophone. Also it gives an added reason why lithophone is especially suited for interior painting.

In conclusion, I hope that this work will prove a basis for many new investigations of both the practical and scientific aspects of the chemical action of light on dyes and paints.

The Disinfection of Swimming Pools

The danger of the transmission of disease in swimming pools is becoming realized more prominently with the growing popularity of these institutions. The management of public baths in such a way as to guarantee a satisfactory degree of sanitary safety has raised a series of questions involving construction, equipment, water source and supply and personal hygiene. Calcium hypochlorite has been highly recommended for disinfecting, and has been adopted for many pools. Its efficiency as a disinfectant for the water is not doubted. Its use, however, gives rise to frequent complaints on account of the disagreeable odor attending it. This has led to much experimentation in search of an equally efficient and less offensive substitute. The difficulties here referred to are decidedly greater in connection with swimming pools than with public water supplies. For the treatment of the latter, more than two parts per million of hypochlorite are seldom necessary. Even with this small proportion, aeration of the drinking water is necessary to overcome the objectionable taste and odor. In the case of the swimming pool, this feature is aggravated by the fact that, three parts of the hypochlorite per million are necessary to sterilize the water. Aeration in such cases merely serves to release the odor from the water into the inclosed room surrounding the pool. In tests conducted recently at the Taylor Gymnasium pool at Lehigh University, South Bethlehem, Pa., encouraging results have been secured by the employment of copper sulphate in place of calcium hypochlorite. The advantage of copper sulphate over calcium hypochlorite as a disinfectant for swimming pools is that it does not undergo chemical change readily. Hypochlorite owes its power to the chemical reactions involved in liberating chlorin, whereby it is converted into a useless product. Copper sulphate is not irritating to the eyes and mucous membranes, as the hypochlorite may be when used in germicidal quantities. It is cheaper and has no odor. If all other conditions were equal, says *The Journal of the American Medical Association*, the last fact alone would prove to be a great advantage.

Fusible Boilers Plugs

The Bureau of Standards has made an investigation of the question of fusible boiler plugs, and as a result, it is stated that there would be almost complete immunity from explosions of fusible plugs of tin of 66.6 per cent purity, and entirely free from zinc.

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